Build it and they will come: The convening power of the SOLEIL Synchrotron facility

Highlights

This case study casts a novel perspective on research evaluation by focusing on the role of a large research infrastructure—the SOLEIL Synchrotron—in the advancement of science. An approach is established for identifying relevant publications, which are then analyzed and visualized using sophisticated but accessible software tools to generate insights.

The SOLEIL Synchrotron is fulfilling its mission to enable research across a broad range of topics and to act as a convening point for researchers collaborating in teams, which are often co-ordinated around the facility’s beamlines.

The SOLEIL Synchrotron is also part of a multinational network of collaborating research institutes and other synchrotron facilities. Patent citation analysis demonstrates that research at the SOLEIL Synchrotron contributes to innovation and economic outcomes.
The role of large research infrastructures in the advancement of science

The emergence of “big science” in the post-war era (de Solla Price, 1963) was characterized by growth in national R&D budgets in many countries and increasing rates of international researcher mobility and international research collaboration. One of the outcomes of these drivers has been the creation of numerous national and international research infrastructures and facilities built on a scale previously not possible, with an aim of fostering technically complex and highly collaborative research across users from around the world. These infrastructures, often research instruments such as computers, telescopes, particle accelerators or monitoring systems, would previously have been impossible for individual research institutions to build and maintain alone because of their sheer cost. Once created however, they could serve as focal points to bring together scientists from different backgrounds in the common pursuit of knowledge.

In France, several Very Large Research Infrastructures are known collectively as très grandes infrastructures de recherche (TGIR) and are managed nationally or through international partnerships (formed by the French National Centre for Scientific Research, or CNRS) and other institutions. An important example is the SOLEIL Synchrotron (see box “What is a synchrotron?”), operated under the jurisdiction of the CNRS and the French Alternative Energies and Atomic Energy Commission (CEA). Situated a few kilometres from Paris and covering an area the size of two football fields, the SOLEIL Synchrotron has been operational since 2008 and attracts thousands of academic and industrial users each year.

What is a synchrotron?

A synchrotron is a source of electromagnetic radiation which can be used to ‘look inside’ very small objects, like a bigger and more powerful microscope with resolution down to billionths of a meter. The synchrotron is a particle accelerator that works by accelerating electrons through a series of magnets to almost the speed of light before they enter a circular track called a storage ring. There, more magnetic devices “wiggle” the electrons to make them lose energy in the form of light. This synchrotron radiation is then directed into one of several experimental stations called beamlines, where it is used to analyze a sample of material (solid or liquid, of inorganic or biological origin). The light produced spans a range from infrared through visible light to X-rays.

“Soleil” in French means “sun,” hence the SOLEIL Synchrotron was named by back-formation from the phrase “Optimized Light Source of Intermediate Energy to LURE” (Laboratoire d’Utilisation du Rayonnement Électromagnétique). In fact, SOLEIL is 10,000 times brighter than sunlight!

The outcomes and impacts of research are typically evaluated from the perspective of its producers (researchers, research institutions and countries) and through the lens of standardized subject classifications. In this case study we offer a novel perspective by making a research-enabling infrastructure – here, the SOLEIL Synchrotron – the evaluated entity. We ask several questions about its role in the advancement of science: What is the topical focus of the research using the facility? Who are the users of this infrastructure, and how are they connected through collaboration at the levels of individual researcher, institution and country? How does the instrument contribute to economic outcomes, measured through influence on patents?

This case study establishes an approach to the delineation of the publications that result from the use of the SOLEIL Synchrotron (and from similar synchrotron facilities in operation around the world) and shows how sophisticated, but accessible, analytical and mapping software tools can be used to generate evaluative insights. The same approach can be extended to other research infrastructures globally.

The origins of this White Paper can be traced to a 2019 report by Mission Publimétrique (2019) which called for the development of research metrics and indicators to evaluate the performance of TGIR relative to their mission. Mission Publimétrique and ICSR have collaborated on this case study of the SOLEIL Synchrotron to demonstrate a scalable and generalisable approach.
Research at the SOLEIL Synchrotron is broad-ranging, with a growing focus on graphene research.

The breadth of research performed using the SOLEIL Synchrotron can be visualized by creating a term map of knowledge production enabled by the facility. The advantage of this approach is that it allows the terms used by the authors of these publications themselves to be examined, rather than relying on any external classification scheme that may not be sufficiently fine-grained to detect niche topics or emerging research fronts.

The first step is to identify all publications that have used the SOLEIL Synchrotron (see box “Identifying research publications using the SOLEIL Synchrotron”). Next, this set of publications can be analyzed and visualized using a freely-available software tool called VOSviewer, which extracts relevant terms from publication titles and abstracts to create co-occurrence networks, and places those used together frequently close to each other on the resulting map.

The SOLEIL Synchrotron term map is shown in Figure 1, and the topical clusters in Panel A clearly reveal the diversity of research conducted using the facility. Clusters of terms relating to the broad domains of physics, materials science, chemistry and life science are clearly delineated from each other, but also show direct connections through bridging terms that may relate to topics of interest that span disciplinary interests or that may reflect terms used in different contexts in different fields. For example, the term “iron” is mapped within the chemistry cluster but is used across these four domains in relation to very different topics, ranging from the elemental composition of cosmic dust to the role of iron sensing in bacterial survival. Nonetheless, this map clearly confirms that the SOLEIL Synchrotron is fulfilling its stated purpose to support “fundamental research needs in physics, chemistry, material sciences, life sciences (notably in the crystallography of biological macromolecules), earth sciences, and atmospheric sciences” (SOLEIL).

The graphene sub-cluster within the materials science domain (bottom left) becomes more obvious when the map is viewed through the lens of the mean publication year of those publications associated with each term in Panel B. Although the graphene research “gold rush” began in the mid-2000s (Plume, 2014), research on this material...
Figure 1. SOLEIL Synchrotron term map. Full counting (count of occurrences, not binary present/absent) was applied to terms in titles and abstracts of 3,091 publications in the period 2014-18, and those with at least 14 occurrences (604 terms) were mapped. Node size indicates count of occurrences, and node proximity reflects frequency of co-occurrence (nodes close together co-occur more frequently than node far apart). Map was reduced to 300 visible edges for visual clarity. In Panel A, colors indicate topical clusters; in Panel B, color scale indicates mean publication year of publications associated with the mapped terms; in Panel C, color scale indicates mean normalized citations of publications associated with the mapped terms. The normalized citation count is the number of citations of the associated publications divided by the mean number of citations of all publications in the same year and included in the mapped data.
continues to grow apace and the use of the SOLEIL Synchrotron as an analytical tool accelerated during the period 2014–18. Moreover, beyond the relatively well-cited topics in the life sciences cluster, these graphene-related publications have attracted high citation impact (Panel C), illustrating the importance of this topic within the research community.

Research at the SOLEIL Synchrotron is highly collaborative and is co-ordinated around beamlines

To understand who uses the SOLEIL Synchrotron and how they work collaboratively, the same underlying publication set used for term mapping can be analyzed and visualized using VOSviewer as a co-occurrence network aggregated at the level of the authors of those publications. This approach adds context and permits a richer interpretation of collaborative patterns than is possible with simple lists of productive scientists.

The SOLEIL Synchrotron author map is shown in Figure 2, with the collaboration clusters in Panel A revealing the sub-networks of collaborative links that reflect research teams with shared scientific interests. For example, the cluster containing Cambillau and Spinelli and their co-authors (on the left side of the map) reflects a series of publications spanning the full period 2014–18 on the structure and function of bacterial receptor proteins and secretion systems.

The SOLEIL Synchrotron is organized around 29 experimental stations called beamlines (see box “What is a synchrotron?”) each of which is led by a beamline manager. Since each beamline manager is a scientist as well as a facility manager, typically they also are publishing research actively using the beamline that they manage. The co-ordinating function these beamline managers serve in the collaborative networks of recurrent users of the SOLEIL Synchrotron is revealed by their central positions in the network of co-authorship relationships shown in Panel B. For example, the aptly named Solari is the manager of the MARS beamline, which is dedicated to the characterization of radioactive material samples, and the publications from Solari and co-authors are largely devoted to this topic. Nonetheless, direct co-authorship connection to these managers is clearly not a prerequisite for regular use of the facility, as numerous sub-networks not directly associated with them are also active users. Some of these groups are relative newcomers to the facility, as seen in Panel C; the cluster that includes Lhuillier, Ithurria and Livache on the left of the map appeared mostly since 2016 and is focused on graphene and other nanostructures. Some groups attracting high mean citation impact to their published work using the facility include the one connected to DESIRS beamline manager Nahon, but primarily feature Meierhenrich and Meinert (Panel D), who have pursued a program of research on how the chirality or “handedness” of biological molecules on Earth may have arisen from extra-terrestrial sources.

The extent and diversity of the collaborative relationships shown in these maps is evidence of SOLEIL Synchrotron’s function as “a service platform open to all scientific and industrial communities, and a centre for exchanges where we spread scientific and technical knowledge” (SOLEIL).

Identifying research publications using the SOLEIL Synchrotron

A publication set was created for all publications acknowledging the use of the SOLEIL Synchrotron and/or listing SOLEIL Synchrotron among the authors’ affiliations. This publication set was based on the deduplication of two sources: a subset of a self-reported list of publications maintained by SOLEIL that are included in Scopus, which was supplemented and extended with a lexical query over Scopus tuned for high precision and recall. VOSviewer (CWTS, Leiden University) and SciVal were used to analyse the data. See Method & Data Sources for more details.
Figure 2. SOLEIL Synchrotron author map. Fractional counting (where links are weighted by count of co-authors) was applied to all authors of 3,091 publications in the period 2014-18, and those with at least 7 occurrences (490 authors) were mapped. Node size indicates count of occurrences, and node proximity reflects frequency of co-occurrence (nodes close together co-occur more frequently than node far apart). In Panel A, colors indicate collaboration clusters; in Panel B, colors indicate beamline leaders (orange) and SOLEIL Synchrotron director general (red); in Panel C, color scale indicates mean publication year of publications associated with the mapped authors; in Panel D, color scale indicates mean normalized citations of publications associated with the mapped authors. The normalized citation count is the number of citations of the associated publications divided by the mean number of citations of all publications in the same year and included in the mapped data.
The SOLEIL Synchrotron is part of a multinational network of collaborating research institutes and other synchrotron facilities.

To place the SOLEIL Synchrotron in the context of its links to other national and international organizations, a publication set was created using a version of the Scopus lexical query to supplement the SOLEIL publication set, but without the exclusive focus on the SOLEIL Synchrotron (see Method & Data Sources for more details). The resulting publication set can be analyzed and visualized using VOSviewer as a co-occurrence network aggregated at the level of the institutional affiliations of the authors of those publications, which may include universities, research centers and other synchrotron facilities.

The map of institutional affiliations associated with synchrotron-enabled research publications is shown in Figure 3. SOLEIL itself features very prominently amid a large cluster on the left of the map, consisting exclusively of French universities and institutes (among them its principal sponsors CNRS and CEA). Extensive co-authorship linkages connect this cluster to a European sub-network (center of the map) which includes several other synchrotron facilities, and which in turn shares collaborative connections to institutions in India, Japan, South Korea, Taiwan, China, UK, Australia, Brazil and the US. Since research is a global enterprise, this broader view on the international connectedness of the SOLEIL Synchrotron and the work conducted there reinforces the value of this French infrastructure investment for the wider scientific community.

Figure 3. Global synchrotron institutional affiliation map. Fractional counting (where links are weighted by count of co-affiliation) was applied to all affiliations of 49,744 publications in the period 2014-18, and those with at least 170 occurrences (200 affiliations) were mapped. Node size indicates count of occurrences, and node proximity reflects frequency of co-occurrence (nodes close together co-occur more frequently than node far apart). Colors indicate collaboration clusters.
Research at the SOLEIL Synchrotron contributes to innovation and economic outcomes

Direct measurement of the broader societal impacts of research is difficult, and even when such evidence can be collected, the problems of attribution and causality are difficult to resolve (Bornmann, 2012). However, an established approach to linking research with technological innovation and economic outcomes is taken by examining the patterns of cited references to the published research literature in patents. The same publication sets for the SOLEIL Synchrotron and the global synchrotron research output used in the previous analyses were analyzed as custom publication sets using SciVal, which includes patent-publication citation links covering the world’s five largest patent offices: European Patent Office, US Patent Office, UK Intellectual Property Office, Japan Patent Office and World Intellectual Property Organization (WIPO). Of the 3,086 SOLEIL Synchrotron publications analyzed, 52 publications (1.7%) have been cited 130 times in 116 different patents, equating to 42.1 patent citations per 1,000 publications. This rate is appreciably higher than that observed across the global synchrotron-enabled set of 49,694 publications analyzed, of which 634 publications (1.3%) have been cited 1,452 times in 1,314 patents, at a rate of 29.2 patent citations per 1,000 publications.

The country from which patent assignees (applicants/owners) most commonly lodged their applications was France, but the United States, Belgium, United Kingdom and Germany are represented prominently as well. These patents cover a wide range of invention claims, including vaccines and antibodies for the prevention and treatment of infectious diseases such as dengue fever and zika virus all the way through to methods and apparatus for cost-effective radiation detection.

Conclusion

This case study has demonstrated how a novel approach to research evaluation—taken from the perspective of a large scientific infrastructure such as the SOLEIL Synchrotron—can illuminate the role of such facilities in the advancement of science and their convening power for collaborations among researchers, institutions and countries. The approach used here can be applied to other such entities to answer evaluative questions about knowledge production and real-world outcomes of the science they support.
Method & data

A publication set was created for all publications acknowledging the use of the SOLEIL Synchrotron and/or listing SOLEIL Synchrotron among the authors’ affiliations. Two sources were used. The first was a self-reported list maintained in the SOLEIL Publications library (https://www.synchrotron-soleil.fr/en/publications), which was matched to Scopus coverage using the DOI (Digital Object Identifier) associated with each publication. Scopus is Elsevier’s abstract and citation database of peer-reviewed literature covering 80 million documents published in over 22,500 journals, book series and conference proceedings. Data for this report was accessed in Scopus in January 2020. To focus on original peer-reviewed publications, the search was restricted to articles or conference papers published in journals or conference proceedings in the period 2014-18.

To supplement this publication set, a Scopus lexical query was created to identify publications using the terms ‘beamline’ OR ‘synchrotron’ along with the term ‘SOLEIL’ in the title, abstract or keywords or in the (funding) acknowledgements, or where one or more authors listed SOLEIL as their affiliation. Again, to focus on original peer-reviewed publications, the search was restricted to articles or conference papers published in journals or conference proceedings in the period 2014-18. A high degree of precision was verified by visual inspection of 100 retrieved publications, stratified by citation impact and publication year. The two publication sources were merged and deduplicated, and the Scopus publication data was exported to a file for subsequent analysis.

To create a global view on publications using any synchrotron facility, a version of the Scopus lexical query described above was created and is identical to the one described above, but without the requirement to include ‘SOLEIL’ in the title, abstract or keywords, acknowledgements or author affiliations.

These publication sets were analyzed and visualized using VOSviewer (CWTS, Leiden University) and SciVal. Term co-occurrence maps and collaboration maps were created using VOSviewer (CWTS, Leiden University) according to mapping parameters detailed in the caption for each figure. SciVal-based analyses were created after building custom publication sets.

Plume, Andrew (2020), “Data for: Build it and they will come: The convening power of the SOLEIL Synchrotron facility”, Mendeley Data, V1, doi: 10.17632/td4k3rjm7.1
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