A Synchrotron as Accelerator of Science Development in Central America and the Caribbean

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ABSTRACT

Central America and the Caribbean (CAC) need science development efforts through ambitious projects that require strong regional collaboration. Inspiration can be drawn from initiatives in regions with similar problems.

The bottleneck is the scarcity of public research centers and little or no research in private universities. The "Central American Science and Technology Fund" proposed by the government of Guatemala, is pending a decision by the Summit of Central American Heads of State. An interesting proposal is the creation of a Dominican "Silicon Beach". The "Central American Science and Technology Fund" should focus on objectives capable of attracting the attention of the non-academic sector, first and foremost policy makers, but also civil society in general. This support is necessary to transmit in the project that of the regional development banks, in possible synergy with the Inter-American Development Bank and the World Bank.

The successful experience of SESAME (" Synchrotron Light for Experimental Science and Applications in Middle East ") offers an interesting basis for reflection, as it allows scientific research and short-term practical and social applications. Only two of the more than 60 existing synchrotrons are in Latin America, both in Brazil. Latin America deserves to have at least one more synchrotron, whose versatility will help reduce the need to send young students abroad, and reduce the brain drain. Together with other similar projects in the South, such as the African Light Source (AFLS), and with the support of SESAME, LNLS and other synchrotrons in the South, it could lead to interesting South-South cooperation, which could be supported by the European Union or the NSF.

As David Gross reminded, Science drives Technology, Technology drives Innovation, and this ends up in the welfare of society. A regional synchrotron may be the way to make this a reality in the Great Caribbean Region, as a first historical example of a large regional facility there.

INTRODUCTION: RECENT EVOLUTION OF SCIENCE IN LATIN AMERICA

Science is known to play a key role in the development of nations. In particular, Physics has been instrumental to the global technology advancement in the last 100 years in the World, but in Central America, it is less developed than in the rest of Latin America, as it is confirmed by periodical analyses that, despite showing an undeniable progress, call for an acceleration in the scientific policy of the region, noting the significant gap with respect to the rest of Latin America.

A reorientation of national and regional science and technology policies in favor of basic science in general may certainly be necessary and useful, but, without the courageous decision of committing the region in ambitious projects, future analyses will continue to register the same situation. Zeno’s slow progress is not the solution, rather a Copernican revolution is needed.
Accordingly, the purpose of this Note is twofold: to show that this revolution is possible and only requires a political decision and to provide to policy-makers and civil society the background information they may need to make or support such decision.

The acceleration of science is a matter not only of concern to CAC but also to developed countries. Examples of strategic alliances on scientific research and technological innovation, are the Common Research Area between the European Commission and CELAC countries, and the Partnerships for Enhanced Engagement in Research (PEER) program, administered by the NSF of the USA.

In Central America, between 1966 and few years ago, the only important regional activity in Physics has been the Central American Courses of Physics, the CURCAFs, promoted by Robert Narvaez Little (University of Texas at Austin), under the umbrella of the Central American Physical Society, SOCEF. CURCAFs’ model was the Latin American School of Physics, ELAF, created in 1959 by the mythical fathers of Latin American Physics, Juan José Giambiagi, José Leite Lopes and Marcos Moshinsky. CURCAF’s main focus was the improvement of the teaching method of Physics at school level, much under the influence of the PSSC project, whereas ELAF’s refocused attention on advanced research. The major organizations that contributed to the flourishing of both initiatives were the Organization of American States, UNESCO, and the intergovernmental Latin American Center of Physics, CLAF, created by UNESCO in 1962, that has recently established a regional Central American headquarters in Costa Rica.

In the early 1980s, Dominican Republic joined CURCAFs, and a second C, for “Caribbean” was added. This was one of the first participations of the Dominican Republic in the not always appreciated complex and variable-geometry process of regional integration. The regional integration of Dominican Republic would be strengthened in 2012, with its adhesion to CSUCA (Higher Central American University Council) and in 2013, with that to the Central American Integration System, SICA.

In the 1990s, in the framework of a program for the post-civil-war reconstruction of Universidad de El Salvador (UES), a conference to draw a regional plan for Science and Technology was held at UES. Instrumental were the visionary support of the UES Rector, Fabio Castillo, and the understanding of the supervisors of the program in Brussels.

At the turn of the new millennium, the need of launching Physics Masters programs in the region was addressed. A few years later, CSUCA’s secretary general, Juan Alfonso Fuentes Soria, and the fourth director of the “Abdus Salam” International Center of Theoretical Physics, ICTP, Fernando Quevedo agreed that two regional Ph D programs, in Physics and Mathematics, were needed, and their creation was proposed. These doctorate programs were approved by CSUCA in 2012, and started operating in 2014, with the Physics program at UES and at the Universidad Tecnológica de Panamá, and the Mathematics program at the Universidad de Panamá. Their success has been moderate, and the participation limited. However, despite these pitfalls, they are most certainly a milestone in the higher-education policy of the region, because of the harmonization of the programs and the recognition of credits and titles by participant universities.

The seed has been fruitful. Currently, SICA and the Canadian International Development Research Center are supporting the development of an RCN (Network of Natural Sciences), which leads to a future of positive scenarios. Its expected results are a strengthening of the Physics regional doctorate, an extension to Biology and Chemistry and the fostering of a broad network of regional collaboration, with much less dependence on the goodwill of individuals.
There are also a few national science-related doctoral programs. For example, at INTEC, which is a Dominican private university, there are three Ph D programs, on Environment, Energy Management and Engineering. Also in the Dominican Republic, a Mathematics doctorate is interestingly run by a public-private consortium of three Universities, although it is unclear why no synergy with the regional CSUCA program has been sought.

These programs can reduce, although only marginally, the need for Ph D studies abroad, that often end in brain drain, a problem that tends to be general, not only for the developing countries. In the region, the mitigation of the effect of brain drain has been pursued by yearly scientific meetings, such as Convencencia in Guatemala and the International Congresses of Scientific Research of the Dominican Ministry of Higher Education, Science and Technology. Another similar program, the Encuentros Científicos Internacionales takes place in Peru, as well as other initiatives aim to take advantage of the scientific diaspora, such as the Argentinian RAICES network, the ephemeral Red Caldas in Colombia, now limited to country clusters and the UNDP-UNV TOKTEN Program.

THE LOCAL IMPACT OF SCIENCE

However, local high-level training and utilization of the diaspora’s expertise are just a first step. Their local impact is null, unless these trained scientists may find an adequate research environment and real opportunities. The bottleneck is that public research centers are few and private research almost inexistent. Thus, universities, often with heavy teaching schedules and small amounts of research, remain the almost unique available providers of employment, just as it was more than fifty years ago.

Two other mechanisms to foster regional scientific progress have actually been proposed. The first is the creation of regional Centers of Science, using the model of ICTP. Forty years back, Abdus Salam, who had just received the Nobel Prize for Physics, promoted the creation or development of “triestinos”, i.e. Trieste-like, centers worldwide. It was a big international project that culminated in a Conference at ICTP Headquarters in Trieste and in Salam’s unsuccessful attempt to receive financing of the initiative.

In the US, a triestino center was created by initiative of Marshall Luban and James Vary at Iowa State University. For almost a decade it played a complementary role to ICTP, especially in Africa. Moreover, at Fermilab, Leon Lederman and Roy Rubinstein, promoted collaborative programs with Latin America.

In Latin America, Salam’s program included the Instituto de Estudios Avanzados, IDEA, in Venezuela, Multiciencias, in Peru, the Centro Internacional de Física, CIF, in Colombia, and the Centro Internacional de Física y Matemáticas Aplicadas, CIFMA, in Mexico, this last one through Salam’s Deputy, Luciano Bertocchi. The last three centers had a close and strong interaction. CIF had a representation office in Lima (and another in Quito) and its experience was frequently shared with Mexico. Unfortunately, Multiciencias did not survive the Peruvian economic crisis of the so-called lost decades. Instead, CIF and CIFMA are still active, and CIF has been recognized by TWAS as a developing-country Center of Excellence.

In the last decade, the idea was brought back to life, thanks to Fernando Quevedo mentioned previously. With ICTP support, a few aligned Centers were created worldwide and recognized by UNESCO as Category 2 Centers. Two of them are in Latin America, the Mesoamerican Center for Theoretical Physics, in Mexico, and the South American Institute of Fundamental Research, SAIFR, in Brazil. The
former includes in its mission collaboration with CAC and the Andean region. In the Andean region, similar attempts took place in Colombia and Ecuador, and in the Caribbean, where a center on Materials Science, CRICMA, has been proposed. Despite initial enthusiasms, their implementation failed for different reasons that could be interesting to analyze, even if it goes beyond the purpose of this Note.

Obviously, Physics research by individual groups is also carried out, and regional networking is growing, thanks to the existence of very high-level niches in most CAC countries, and to the RCN experience. This is not limited to groups with a strong historical regional vocation, but also reflects policies of excellent institutions like the Pontificia Universidad Católica Madre y Maestra (PUCMM), with its projects of a Masters Program in Physics and a doctorate in Materials Sciences.

However, in countries that fund science with less than 1% of their GDP, (in some cases even less than 0.1%), the first most pressing need is to effect significant increases in this financing. This may happen through an instrument originally proposed in a CSUCA doctorates meeting, that acquired consent when Guatemala’s vice-president, Juan Alfonso Fuentes Soria, proposed it, on behalf of his government, to the 2015 Central American Summit. It consists on a Central America Fund for Science and Technology. The proposal has been observed with interest, but the final decision for its creation, which is in the hands of the Summit of the Central American Heads of State, is still pending.

The purpose of the Fund for Science and Technology is not to increase the current national support to science and technology by some scaling factor, but rather to foster broad-scope regional initiatives, like doctorates or the establishment and management of advanced research centers, possibly stimulating a boost of the private sector participation.

POTENTIAL VENUES

The central question, however, is this: would strengthening the doctorates, having research centers and having the Fund in place be sufficient to develop CAC Physics and Science at a pace comparable with that of other Latin American countries?

The plain answer is: most probably not!

The absence of interest and support, by the civil society, the press, the private sector and the political sector is notorious.

In a webinar organized by the Konrad Adenauer Guatemala Foundation, on the Challenges for the region, the emphasis was on economics, trade, politics, mentioning it is true, problems like health, education and food security, but missing the necessary condition for any sensitive policy in these areas, a solid scientific culture of the region.

Certainly, some interesting ideas still appear. For example, the Dominican president, Luis Abinader, announced the intention of creating a Silicon Beach, a city of knowledge, to some extent similar to that put in place by Panama in the former Canal Zone, that has contributed to a remarkable scientific development in the last two decades. There is no doubt that such a proposal may have a tremendous impact for the development of the country and of the entire region. However, six months after that announcement, no concrete actions have been made, nor was it mentioned again at president Abinader’s presentation of the first-year results and future programs of his government.
It must be stressed that the purpose of establishing a regional Fund is not to allow politicians to claim that their plans of country development do not neglect Science. The mechanism will not produce significant effects, unless it is used to allow the region to realize the ambitious programs it needs that cannot be realized under the current financing conditions.

The success of the Fund will be measured by its capacity to implement such programs and in a reasonably short-time frame. It is a goal that cannot be limited to Central America and Spanish-speaking countries. Caribbean members of Caricom and the Association of Caribbean States, ACS, must also be involved.

Thus, the Fund will make possible a regional science policy focused on goals that may attract the positive attention of the non-academic sectors. Their support to the recognition that scientific and technological development must be a state priority is a necessary condition to make possible such a change of paradigm. If this happens, it is foreseeable that the regional development banks operating in the region, and whose crucial importance for the regional development has been stressed in the mentioned webinar, may play a more active role, in synergy with the broader-scope Inter-American Development Bank and World Bank.

However, what could be such an ambitious program? The relation between science and society is complex, and, unfortunately, it has been usually analyzed through the lenses of advanced countries.

The prejudicial idea that developing countries must limit themselves to socially and/or economically useful science is not so appealing anymore. The well-known sentence attributed to Faraday about taxes that would come from apparently non-applicable research applies to them, as well.

Approximately 15 years ago, Jean-Paul Fitoussi warned that “a naive conception of research aimed to obtain quick results may prevent financing fruitful projects if they do not appear susceptible of practical applications. … This may be normal for socially efficient public policies, but it risks to ignore important projects”. About 15 years before that, Galileo Violini and Marcello Cini, the coauthor of “The bee and the architect”, bibles of the neo-Marxist approach to the relation between science and society, had reflected on certain peculiarities of this relation in developing countries, and this favored, to some extent, the Andean participation first in Fermilab and then at CERN, and paved the way to a collective study CIF promoted ten years later, in collaboration with CERN, Fermilab, ICTP and TRIUMF. However, they referred to small investments intended to allow to satisfy personal research vocations. If very ambitious and expensive national projects are at stake, one cannot ignore, as Fitoussi recognizes, their cost of opportunity, in particular, in countries with great problems of social equality, and this applies especially to the present times, because of the economic impact of the COVID pandemic.

A SPECIFIC PROPOSAL

In this context, the successful experience of SESAME, (Synchrotron Light for Experimental Science and Application in the Middle East) offers interesting elements to reflect on. Beside its scientific value, it also satisfies the requirement of practical and socially useful applications, and this happens in countries of economic capacity and scientific tradition-culture not much different from CAC.

At the end of last Century, when Germany was going to dismantle its Bessy-1 synchrotron and to put in place a new one, SESAME started as the proposal of relocating Bessy-1 in Middle East. The idea received a strong support from Herwig Schopper (CERN) and Herman Winick (Stanford). Jordan was
chosen to be the host country for SESAME. The limited specific experience of the scientists in most participating countries was not a problem because the time required to start operations was used to realize a strong several-year training program. Eventually, SESAME opened in 2017\textsuperscript{38} and now it is a successful regional laboratory.\textsuperscript{39}

In fact, six beamlines have been commissioned, with plans for a seventh. Demand is high, with 151 proposals between the first call in December 2016 and the third in November 2019. Between July 2018 and February 2020, experiments have been conducted for 62 of them, involving 12 different countries, many of them collaborative projects. Its outreach activity included hosting another organization’s workshop on its premises, that of the Association of Arab Universities. SESAME’s solar power plant, inaugurated in February 2019, makes SESAME the world’s first large accelerator complex to be fully powered by renewable energy and the world’s first carbon-neutral accelerator laboratory.\textsuperscript{39}

A few years ago, there were about 60 synchrotrons in the world\textsuperscript{40}, but now there are a few more. About one third of them are located in the American continent. Among them, only two are South of Rio Bravo, the physical, non-anthropic, border between US and Mexico. They are both in Campinas, Brazil. One is the LNLS, built in 1997, and the other a fourth-generation synchrotron, SIRIUS, inaugurated in 2018. As a comparison, the energy of LNLS is 1.37 GeV, and that of SIRIUS, whose radius is about five times larger, 3 GeV.

This makes it appropriate to recommend that having at least one more synchrotron be recognized as a priority in Latin America. One could wonder whether for this it may be convenient to relocate the old Brazilian machine. But this is a detail and cannot be \textbf{THE} reason whether to put in place or not a synchrotron as we propose.

Latin America deserves it anyway.

The variety and versatility of synchrotron capacities may help overcome the need of sending students and young scientists abroad. Synchrotrons can be used for biological, chemical and physical research. A short list of possible applications includes structural molecular biology, molecular environmental science, surface and interface science, micro-mechanical devices, x-ray imaging, archaeological microanalysis, materials characterization and biomedical applications.

We recall that, while the possibility of a large-scale production radio isotopes (RI) from photons was considered very unlikely in 2009\textsuperscript{41}, now -- at least at the proof-of-concept level-- it seems highly probable, because of the great progress in the use of electron accelerators and synchrotrons.\textsuperscript{42} This suggests that this might be the dominant method for RI production in the next decade.\textsuperscript{43}

Therefore, such a facility will not only benefit Physics. It will benefit Science in general, contributing to scientific development and to tackle and solve many national and regional problems, but there are also other aspects to underscore.

\textbf{CONCLUDING REMARKS AND EXPECTATIONS}

The availability of such a facility will have impact on the training of graduate students, postdoc, and other young scientists, who will no longer have to go abroad to pursue their scientific interests. This has been the case in countries such as Taiwan and South Korea, where national facilities built many years ago have significantly reduced brain drain, and encouraged their scientific diaspora to return home. Of course, a word of caution may be opportune. The building of a new facility, and this happened for
example in Trieste, when ELETTRA, the synchrotron of the Trieste Research area, was built, or in Frascati in the 60’s, triggers a surge in physics enrollments, which may last for quite a while. Obviously initially this is viewed as “good”, at least by the physics department itself. After all, especially these days, a doubtful neoliberal justification of the role of the universities may be based on indicators of this sort. It is obvious that the facility can only absorb a fraction of the increased number of local graduates in physics, and this may eventually lead to a problem of internal brain drain, unless its creation is accompanied by a development of the demand of graduates. However, in the specific case of CAC, where a large number of universities do not offer physics careers, and not even have Physics departments, it is likely that this risk is reduced.

The construction of a synchrotron will stimulate local industries, including services, suppliers of all sorts, new high-tech companies attracted to the site, etc. Some of these would later take advantage of its capacity. Qualified technicians, highly needed in the region and in the rest of Latin America, will be trained, and this can be of the utmost usefulness in other branches of research, like Astrophysics, an area of growing importance in the continent, even if not particularly in CAC, as well as in several industrial activities that require such expertise, thus opening opportunities for job creation and industrial development.

Another important perspective is Scientific Diplomacy. SESAME, with a membership including Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey, is a proof of the capacity of science to promote the dialogue and to realize the goal UNESCO states in the preamble to its constitution “to construct the defences of peace in the minds of men and women”. Spanish-speaking Central America has been a leader in regional integration, but still much has to be done for a Great Caribbean integration. This project can contribute to this goal.

It is foreseeable that if the project of a CAC synchrotron materializes, it may count on a vigorous international cooperation. At a scientific level, this happened for SESAME, and we would dare to believe that SESAME will certainly be an enthusiastic supporter of an initiative born from its experience. ICTP can be instrumental to receive support from ELETTRA. We also have reasons to believe that a valuable support will come from the Brazilian and some US synchrotron.

Another initiative that may be useful for this purpose is LAAAMP (Utilization of Light Source and Crystallographic Sciences to Facilitate the Enhancement of Knowledge and Improve the Economic and Social Conditions in Targeted Regions of the World). It was launched in 2017 as a cooperative effort between IUPAP and IUCr to promote synchrotron radiation and crystallographic sciences in Africa, Mexico, the Caribbean, Southeast Asia, Middle East and the Pacific Islands. The project was supported by a grant of the International Science Council (ISC). LAAAMP focuses on training young researchers, reaching out to professionals such as university faculty, and engaging the public and governmental officials in discussions about the role that advanced light sources and crystallographic sciences could play to improve their countries’ educational institutions, economies, social structures, health and world competitiveness.

It is necessary that these possible sources of support materialize as soon as the project is approved, in order to start a strong program of training. In fact, the need to ensure the operation and maintenance of the facility requires the launch of a large-scale program of human resources training, as it happened for SESAME. This training may require a few-year program, and possibly some conversion of theorists to experimental physics. This would be a courageous, not always easy, personal choice, but this is how High-Energy experimental Physics developed in Mexico, with Clicerio Avilez, and in Brazil, when Jayme Tiomno, in a conversation at Fermilab’s cafeteria witnessed by one of the authors (GV),
convinced Carlos Escobar and Alberto Santoro to make this step, and, specifically in the area of electron accelerators, one finds an example of great results and motivation to follow, that of Bruno Touschek, a theoretical physicist, father of the intersected rings with Frascati’s AdA.47-49

Among some valuable experiences in developing countries, we highlight the cases of the African Light Source (AFLS)50, which includes conferences, schools, training and mobility through a Consortium in that continent, and an analogous project in South-East Europe51. Not only they stress further the need to keep the pace in CAC, but also offer a perspective for a coordinated effort to carry on jointly the required training activity with the possibility of finding external support in suitable European, American or Chinese programs. For this an important role can be played by LAAAMP and by cooperation organizations like DAAD that traditionally have supported South- South cooperation.

Cooperation is crucial in terms of the cost of this project. This would depend on many variables, and in this note we avoided a deep discussion of this point because it could have been a distraction from the central issue. Nevertheless, this cannot be a problem once the political will exists. Because of the COVID-19 pandemic, the Central American Bank for Economic Development gave to each SICA country 50 M US$, more than what would be needed for any reasonable choice of synchrotron characteristics.

Foreign support may come from cooperation for development funds. Their amount has been stable over the last 20 years around 1 billion dollars, (which in real terms means a decrease of about 35%). Current Direct Foreign Investment in the region is of the order of 15 billion dollars)33. The Association Agreement between Central America and the European Union, and the European Union program of support for CELAC infrastructure could be suitable instruments to provide this project international matching funds to an investment coming from the region. The relevance of the project certainly makes it eligible for an IDB support through its Regional Public Goods program. Finally, if, following Germany’s step, it is decided to reinstall the dismantled LNLS in another country, it could be a possibility for Brazil to bear the corresponding costs, either at federal or at São Paulo State level.

These considerations confirm that the feasibility of this project does not critically depend on money.

It may be good to recall a lost-opportunity experience of the region. Forty years ago, the first CIF (actually ACIF) activity was a high-level workshop on Gravitational waves52. Unfortunately, it did not lead to the expected result of catalyzing the birth of a research group that could participate in the detection, on February 11, 2016, of gravitational waves53. This detection was the result of an international effort of 94 research groups, among which Latin American institutional representation was limited to two groups from Brazilian institutions, one of which is the afore-mentioned SAIFR, although one of the spokespersons who made the announcement was Gabriela González, an Argentinian scientist working in a US university54. The majority of the Bogota speakers could not be among the authors of ref. 53, but one of them, Fulvio Ricci, did, as one of the leading Italian participants in the discovery.

What could have been the impact on the Science in all of Latin American region, if an Andean group generated by the visionary CIF workshop had contributed to that historical result?

About two months ago, opening the XVI Dominican Congress of Scientific Research, David Gross advocated for the importance of research excellence, recalling that Science drives Technology, Technology drives Innovation, and this has a final result in society’s welfare.55

A regional Synchrotron can be the way to make this real in the Great Caribbean Region, with the historical significance of being the first example of a big regional facility there.
How can we ensure that these considerations receive the due attention by the civil society, the mass media, and the private sector?

The future will tell whether the scientists of the region will succeed to attract that attention obtaining a thorough diffusion of the project and that the debate is not limited to the academic milieu.

If this happens, hopefully it will lead to a political decision that will determine whether, in the next decades, CAC countries will have the place they deserve among those that “participate in the progress and the movement of natural sciences”.

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REFERENCES

1- UNESCO Science Report: Towards 2030, UNESCO Publishing, 2015.
2- Wray John H., Physics in Central America, Physics Today, January 1967, p.42
3- Mora Patricia, Perspectivas de la Física Médica Centroamericana y Panameña, Ciencia y Tecnología, 17, p. 35-42, 1993
4- Violini Galileo, Physics in Central America, UNESCO report, 1993
5- García Canal Carlos, Diagnosis referred to the Central American Master Degree in Physics, Universidad Nacional de La Plata, 2011
6- Cifuentes Edgar, El XXV CURCCAF y un poco de historia, USAC, 2012
7- Brotóns Antonio Remiro, Las instituciones del sistema de integración centroamericana y su futuro, en Centro América: Perspectivas de futuro, Universitat de Barcelona, 2003, pag. 77-182
8- Vary James, Violini Galileo, Edts., Science and Technology for Central America: Plans and Strategies, Universidad de El Salvador, 1995
9- Quevedo Fernando, Ordóñez Carlos, Violini Galileo, Propuesta de un programa de doctorados en Física y Matemáticas para las universidades del CSUCA, CSUCA - ICTP report, 2012
10- Acta CVII Reunión CSUCA, June 13, 2012, CSUCA
11- Rudamas Carlos, Nitsch Lucia, Violini Galileo, Pazos Enrique, Fuentes Soria Alfonso, La Red de Investigadores para el Desarrollo de las Ciencias Naturales (RCN), una oportunidad para el fortalecimiento de la investigación científica en la región. IX Congreso Universitario del CSUCA, Tegucigalpa, June 2021
12- Nitsch Lucía, Rudamas Carlos, Violini Galileo, Fuentes Soria Alfonso, Necesidad de doctorados regionales en biología y química, IX Congreso Universitario del CSUCA, Tegucigalpa, June 2021
13- Gómez Ramírez, Plácido F., Ciencia e Investigación Científica en República Dominicana, in Gómez Ramírez Plácido F., Incáustegui Sixto, Rodríguez Peña Carlos Manuel, Apuntes sobre Ciencia e Investigación Científica en República Dominicana, MESCYT, 2020
14- Violini Galileo, La fuga de cerebros y sus implicaciones para las políticas de educación superior, Reunión internacional de reflexión sobre los nuevos roles de la educación superior a nivel mundial: el caso de América Latina y el Caribe, UNESCO – CRESALC, 1991.
15- Chang Juan Diego, Quince años de Converciencia, Plazapublica.com.gt, October 20, 2020
16- https://eciperu.net/2017/03/03/ecis-anteriores-prior-ecis/
17- https://www.argentina.gob.ar/ciencia/raices
18- Chaparro Fernando, Jaramillo Hernán, Quintero Vladimir, Aprovechamiento de la Diáspora e Inserción en Redes Globales de Conocimiento: El Caso de la Red Caldas, Report for the World Bank. Knowledge for Development Program, 2004
19- Violini Galileo, La necesidad de una nueva generación de Centros Regionales de Ciencia y Tecnología, in Lemarchand, Guillermo, Relevamiento de la Investigación y la Innovación en la República de Guatemala, UNESCO, 2017
20- Latorre Victor, Abdus Salam en el Perú, Tradición, Segunda época, Revista de la Universidad Ricardo Palma, 16, 132, 2017
21- Fog Lizbeth, Centro Internacional de Física, Libertad para pensar y actuar, 1985-2010, CIF, 2011
22- Flores Valdés Jorge, La gran ilusión: Memorias de un físico mexicano, Fondo de cultura económica, 2018
23- Moore Steven, Posada Eduardo, Violini Galileo, The Project of an International Center of Physics in Colombia, Notas de Física, 6, 76, 1983
24- Llosa Luis Gonzalo, Panizza Ugo, La gran depresión de la economía peruana. ¿Una tormenta perfecta? Revista Estudios Económicos, 30, p. 91-117 (2015)
25- Fog Lizbeth, Excellence in Science, Profiles of Research Institutions in Developing Countries, Centro Internacional de Física, Trieste, 2013
26- Núñez Sellés Alberto J., Piazza Fabrice, Violini Galileo, Regional Center for Research in Science of Materials in the Dominican Republic, (CRICMA-RD) UNEV-PUCCMA report, March 2018
27- Fuentes Soria Juan Alfonso, Fondo Regional de Ciencia y Tecnología del Sistema de Integración Centroamericana, FORCYT-SICA in Lemarchand Guillermo, Relevamiento de la investigación y la innovación en la República de Guatemala, UNESCO, 201
28- Konrad Adenauer Guatemala Foundation, Bicentennial, 4th Session, Challenges of the Central American Region, Web Seminar, September 22, 2021
29- Padilla Vassaux Luis, contribution in ref. 28
30- Abinader Luis, Rendición de cuenta ante la Asamblea Nacional, Ministerio de la Presidencia, República Dominicana, February 27, 2021
31- Violini Galileo, Silicon Beach no es utopía, acento.com, March 31, 2021
32- Abinader Luis, Primer año del cambio, Presidencia de la República Dominicana. August, 18, 2021
33- Deras José E., Retos y desafíos que enfrenta la región centroamericana:enfoque económico-comercial, contribution in ref. 28
34- Fitoussi Jean-Paul, I valori della ricerca, La Repubblica, September 28, 2005
35- Ciccotti Giovanni, Cini Marcello, De Maria Michelangelo, Jona-Lasinio Giovanni, L’ape e l’architetto. Paradigmi scientifici e materialismo storico, Feltrinelli, 1976
36- Cini Marcello, Violini Galileo, Motivaciones para una política científica: reflexiones sobre la necesidad de impulsar la ciencia en los países en vías de desarrollo, Naturaleza, educación y ciencia, 1983
37- Aguirre Carlos, Cresti Marcello, Escobar Carlos, García Canal Carlos, Hoeneisen, Bruce, Lederman L.eon, López Cayetano, Negret, Juan Pablo, Rubio, José Antonio, Teitelboim Claudio, Violini Galileo, Vogt Eric, Report of the Steering Committee for Fundamental Physics, Colciencias, 1993
38- Blaustein Richard, SESAME synchrotron opens for users, Physics World, May 17. 2017
39- Aleisa Esra Elsa, Djefflat Abdelkader, Zou’bi Moneef, The Arab States. In UNESCO Science Report: The Race Against Time for Smarter Development. Schneegans Susan, Straza Tiffany. Lewis John (eds). UNESCO Publishing: Paris, 2021
40- https://www.light2015.org/Home/LearnAboutLight/Lightsources-of-the-world.html
41- IAEA Report Cyclotron Produced Radionuclides: Principles and Practice; Technical Reports Series No. 465, Vienna (2009)
42- Ejiri Hiroyasu, Date S., Coherent photo-nuclear reactions for isotope transmutation, arXiv: 1102.4451
43- Srivastava Yogendra et al, Generation of radio nuclides [64Cu, 62Cu, 18F, 11C] through the giant dipole mechanism, Exploratory Biotechnical Research, 1(2) (2021) 120.
44- Nuccio Ordine, Los estudiantes no son pollos de engorde, El País, September 18, 2021
45- https://laamp.iucr.org
46- Aihara Hiroaki et al., Latin American HECAP Physics Briefing Book, arXiv:2104.06852v1, April 14, 2021
47- Amaldi Edoardo, The Bruno Touschek legacy, CERN Yellow Reports: Monographs 81-19, 2001, doi: 10.5170/CERN-1981-019
48- Pancheri Giulia, Bruno Touschek's extraordinary journey: From death-rays to antimatter. Under completion, to be published. Springer Nature, 2021-22
49- Bonolis Luisa, Pancheri Giulia, Bruno Touschek: Particle Physicist and Father of the e+e Collider. European Physical Journal H, 36(1):161, 2011, doi: 10.1140/epjh/e2011-10044-1.
50- https://www.africanlightsource.org/
51- Ivo Šlaus, private communication
52- Posada Eduardo, Violini Galileo, Edts. Search of Gravitational Waves, World Publishing Co., Singapore 1983
53- Abbott Benjamin P. et al., (LIGO Scientific Collaboration and Virgo Collaboration), Phys. Rev. Lett. 116, 061102
54- https://www.lsu.edu/mediacenter/news/2016/02/11phystasro_ligo2016.php
55- Gross, David, The critical role of the Centers of Science, pg. 79 in: Rodríguez Peña Carlos Manuel, Incháustegui Sixto J., Violini Galileo, Tapia Leandra, Alberto Miledy, Arias Milla Francisco R. (eds), Programa y Libro de Resúmenes del XVI Congreso Internacional de Investigación Científica. 2021
56- Sarmiento Domingo Faustino, Inaugural Speech of the Cordoba Observatory, October, 24, 1871
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