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Mapping the Landscape of Space Sciences in Latin America: a Bibliometric Study of Productivity and Collaboration in Mexico, Brazil, Argentina, and Chile

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Abstract

This paper presents a regional bibliometric study of space sciences in Latin America. The research is conducted in solar physics, magnetospheric physics, physics of solar-terrestrial relationships, cosmic ray physics, and planetary physics, over a 20-years period from 2001 to 2020. The Latin American countries where research is carried out in these areas of knowledge are Brazil, Chile, Argentina, and Mexico.
The results show that Chile has more collaborative networks abroad, as its productivity is considerable in solar physics, solar-terrestrial relationships, and planetary physics; Brazil has been consistent in the number of publications and authors per document in the areas of solar physics and magnetospheric physics and, Argentina collaborates mainly with Brazil in planetary physics. The results also show that the National Autonomous University of Mexico (UNAM) is the leading institution in Mexico conducting research in the field of space sciences.
According to the values obtained from the bibliometric parameters, the productivity of the Mexican research group dedicated to space sciences at the Institute of Geophysics of the UNAM has not increased, at least in the last twenty years.
At regional level, the countries under study have had a deficient scientific development in the five areas of knowledge analyzed, despite the formation of scientific societies and the organization of conferences, seminars, and courses to create working groups and international collaboration networks.

Key words: Bibliometrics, Space Sciences, Latin American countries, Mexico, UNAM.

Resumen

En este trabajo se presenta un estudio bibliométrico de las ciencias espaciales en Latinoamérica con base en los países que realizan investigación en física solar, física magnetosférica, física de las relaciones sol-tierra, física de rayos cósmicos y física planetaria. El estudio se realizó en un periodo de 20 años (de 2001 a 2020) y los países identificados para llevar a cabo el análisis regional, fueron Brasil, Chile, Argentina y México. Los resultados muestran que Chile tiene más redes de colaboración en el extranjero ya que su productividad es considerable en física solar, relaciones sol tierra y física planetaria, mientras que Brasil ha sido constante en el número de publicaciones, así como de autores por documento, en las áreas de física solar y física magnetosférica.
De acuerdo con los valores obtenidos de los parámetros bibliométricos, la productividad del grupo de investigadores dedicado a las ciencias espaciales en el Instituto de Geofísica de la Universidad Nacional Autónoma de México (UNAM- siglas en español), no ha crecido, al menos, en los últimos veinte años siendo la UNAM, la institución más importante en México, donde se realiza investigación, en el campo de las ciencias espaciales.
A nivel regional, los países latinoamericanos bajo estudio, han tenido un desarrollo científico deficiente en las cinco áreas del conocimiento analizadas, a pesar de que se han hecho grandes esfuerzos para contribuir a la integración de América Latina en estas áreas temáticas, a través de la formación de sociedades científicas, de la organización de congresos y seminarios así como de la impartición de cursos para crear grupos de trabajo y redes de colaboración internacional.

Palabras clave: Bibliometría, Ciencias Espaciales, Países Latinoamericanos, México, UNAM.

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1. Introduction

Space sciences encompass a broad spectrum of research areas, including solar physics, cosmic rays physics, magnetospheric physics, solar-terrestrial relationships physics, and planetary physics. These disciplines play a crucial role in understanding the physical processes governing the interactions between the Sun, the Earth, the interplanetary medium, planetary magnetospheres, and cosmic rays. Their relevance extends beyond fundamental research, influencing geophysical applications, space weather forecasting, and planetary exploration. Scientific advances in these fields have been closely linked to major space missions and observational programs, fostering the development of high-impact research.

Research in the field of space sciences in Mexico, first emerged in the 1970s with the creation of the Space Physics research department, in the Geophysics Institute at the National Autonomous University of Mexico (UNAM – acronym in Spanish). The first area in which research activities began was cosmic rays physics. By the 1980s, two new research areas were integrated into the institute's activities: solar physics and the physics of solar-terrestrial relationships and by the 1990s, two new areas were added to the existing ones: magnetospheric physics and planetary physics.

As a result of these areas, various scientific articles have been published on the Sun, planetary ionospheres, the interplanetary medium, magnetospheric dynamics, dust dynamics in planetary rings, planetary atmospheres, cosmic rays, meteoroid dynamics; modulation of terrestrial weather by solar influence, and heliospheric physics, among other topics. Furthermore, these research areas have been closely linked to the space discoveries done by various space missions in the Solar System, which has allowed for the publication of results related to frontier problems.

These five areas of research in space sciences have been developed, to a greater or lesser extent, in some Latin American countries, and one of the useful tools to measure this progress is bibliometrics.

Bibliometric studies are increasingly used to characterize the scientific activity of countries, disciplines, institutions or individuals and despite all its limitations they are now routinely used in the evaluation of science performance (Hicks *et al.*, 2015).

On the other hand, bibliometric studies are important because they allow us to generate an overview of the development of scientific research in different contexts. Several countries have carried it out to find out the level of development of their nations in different fields of research. This is the case of India, which used the tools offered by bibliometrics to understand the structure, dynamics, and development of research in this country and thus develop public policies that support or strengthen the areas of opportunity detected in these analyses (Ministry of Earth Science, Government of India, 2017) or the United Kingdom, that carried out a bibliometric analysis of the results obtained by the British space agency with the funding granted to it (UK Space Agency, 2021). The European Space Agency (ESA) has resorted to these analysis techniques and has also been carried out by region, as is the case of the Association of Southeast Asian Nations (ASEAN), made up of ten nations that focuses on studying the patterns of scientific collaboration and funding (Koh, 2007; Lee, 2007; Oldac and Yang, 2023). With this background and given the importance of knowing the role of Mexico in scientific research in the area of space sciences, a bibliometric analysis was carried out to obtain an overview of the behavior of this branch of science and compare it with the most relevant countries in Latin America, taking into account that, bibliometrics is supported on indicators, which represent indexes or calculations whose main function is to provide quantitative and objective information about scientific activity. (Gauthier, 1998; Hood & Wilson, 2001; Andersen *et al.*, 2006; Dávila, 2009; Salinas- Ríos, 2022).

The ever-growing use of bibliometric indicators for assessing quality and impacts of research has been described as a "*Metric Tide*" (Martin and Irvine, 1983; Donovan, 2007; Ovseiko *et al.*, 2012; Lee *et al.*, 2013; van Raan, 2003; Newman, 2004; Hirsch, 2005; González-Alcaide, 2008; Martin, 2011; Knight, 2012; Cronin and Sigimoto, 2014; Wilsdon *et al.*, 2015; Wouters *et al.*, 2015). According to Larivière (2012), the tide began around 2010. It soon reached Latin America, where science evaluation using indicators such as citations, journal impact factors or h-indices has taken the region up into the *bibliometric bandwagon*, or some years now (Hood & Wilson, 2001; Moed, 2005; Norris & Oppenheim, 2010; Jonkers and Derrick, 2012).

At the same time, bibliometric indicators are also used in the evaluation of institutions, academic programs and grants (Arocena & Sutz, 2001; Buendia Espinosa *et al.*, 2017; Fontes *et al.*, 2020). Scientists themselves use it for a variety of reasons, among them to study the performance of their journals for communities (Bornmann & Daniel, 2005; Weirngart, 2005; Bar-Ilan, 2008; Jonkers and Derrick, 2012; Bornmann *et al.*, 2014; Ellegard, 2018).

Latin America has experienced significant growth in space sciences research over the past decades, with Mexico, Brazil, Argentina, and Chile emerging as key contributors. Despite this progress, several challenges remain, including funding constraints, uneven research infrastructure, and limited access to international collaborations. A comparative analysis of research productivity, collaboration networks, and institutional participation across Latin America can provide valuable insights into how to enhance space sciences research in Mexico.

Despite the increasing use of bibliometric tools, comprehensive studies on space sciences in Latin America remain scarce.

Previous bibliometric analyses in the region have often focused on broader categories such as astronomy and astrophysics, without differentiating between ”near-space” sciences (studied by geophysicists) and deep space sciences (primarily investigated by astronomers and astrophysicists) (Stankus, 1996). This distinction is critical since Web of Science (WoS) groups all space sciences under ”Astronomy and Astrophysics”, potentially overlooking the contributions of geophysical research.

This study seeks to address this gap by providing an in-depth bibliometric analysis of scientific output in space sciences in Latin America, identifying research trends, collaboration patterns, and institutional contributions.

The paper is structured as follows: Section 2 presents the methodology used to conduct the bibliometric study in the five areas of space sciences (solar physics, magnetospheric physics, physics of solar-terrestrial relationships, cosmic ray physics, and planetary physics) in Latin America. Section 3 presents the results by area. For each one, a table is presented showing the most relevant parameters obtained from the bibliometric analysis as well as the results related to the authorship, the documents, and the knowledge structures analysis (conceptual, intellectual, and social). Section 4 contains the discussion and conclusions are at the end of the paper.

2. Methodology

Based on the selected research lines: solar physics, cosmic rays physics, magnetospheric physics, solar-terrestrial relationships, and planetary physics developed in the Space Risks Section and in the Department of Space Sciences of the Institute of Geophysics of the UNAM, the search topics for this work were determined as it is shown in Table 1.

Initially, it was considered to use both Scopus and Web of Science (WoS) were considered as potential sources for building the bibliometric database. However, WoS was ultimately selected because it offers comprehensive coverage and provides richer metadata, allowing for a more robust and detailed analysis. For all research areas, the search queries were selected considering four criteria: publication period (20 years), country (Table 2), topics (Table 1), and the WoS category (Astronomy & Astrophysics).

Subsequently, in order to know if all Latin American countries do research on space sciences, specifically in the five research areas mentioned above, it was necessary to look for the publications number, country by country, during the chosen publication period for this analysis, from 2001 to 2020 (20 years).

In Table 2 the search results for Bolivia, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, French

Table 1. Search topics used in the bibliometric study of space sciences.

Research line	Topics
Solar physics	Solar
Magnetospheric physics	Magnetosphere
Cosmic rays physics	Cosmic rays
Solar-terrestrial relationships	Seasons, climate, solar irradiance, middle atmospheres, upper atmospheres, thermosphere, solar cycle, “space weather events", "green-house gas concentrations", tides, clouds, "sun-earth connections", "space environments", "sun-to-earth models", "solar-terrestrial physics", "earth´s atmosphere", "solar radiation", "solar variability”
Planetary physics	Asteroids, micrometeorites, dusty rings, moon, planet, meteorites, meteoroids, dust, comets, interplanetary medium

Table 2. Publications number of space sciences in Latin-America.

Research line	Publications number in Latin-America	Publications number without Mexico, Brazil, Chile and Argentina	Percentage of publications without Mexico, Brazil, Chile and Argentina
Solar physics	5055	234	4.6
Magnetospheric physics	415	10	2.0
Cosmic rays physics	1398	50	3.5
Solar-terrestrial relationships	1610	93	5.7
Planetary physics	3141	74	2.0

Guiana, Guadeloupe, Guatemala, Haiti, Honduras, Martinique, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Barthélemy, Saint Martin, Uruguay, Venezuela, Mexico, Brazil, Chile, and Argentina, are presented for each research line for the WoS Astronomy & Astrophysics category.

From Table 2, Argentina, Brazil, Chile, and Mexico present the largest number of publications respect to the rest of Latin-America countries, that represent only the 6% of the total of publications, in the 20 years period.

For this reason, only these four countries were selected to perform the Bibliometric study.

The topics listed in Table 1 were defined generically, and the queries were established within the WoS Astronomy & Astrophysics category. Based on both parameters, the queries were established, and from these, the first databases were obtained, which were downloaded from the WoS website in BibTex format for their subsequent analysis in Bibliometrix (Aria and Cuccurullo, 2017).

The resulting databases were very numerous, so it was necessary to refine them because they contained topics of no relevance to the purpose of this work. In the first two lines of research (solar physics and magnetospheric physics), the search was performed through an initial analysis of the database in RStudio using the bibliometrix library, yielding various results. One of them was a list of 50 keywords contained in the database under study. From this list, terms that were not representative of the topic of interest, were selected and discard and a new search was subsequently performed. In this way, the definitive databases for solar physics and magnetospheric physics were obtained for Argentina, Brazil, Chile, and Mexico respectively.

For the other three lines of research (solar-terrestrial relationships, cosmic rays physics and planetary physics), more specific concepts were used, since each research line of study is very broad. Therefore, the topics shown in Table 1 were proposed, based on definitions from specialized texts on these areas of knowledge (Tarbuck and Lutgens, 2005; Lübken, 2012). The last three topic sections in Table 1 were refined using WoS tools, that is, through the analysis of macro, meso, and micro-topics.

Because of using only the authors keywords was not sufficient to obtain results that reflected the work of space sciences, since there were many terms related to *stellar physics*, *galaxies*, and *cosmology*. All these terms were eliminated because they were not the subject of study in this work. As a consequence of this, it was possible to perform a more in-depth refinement and the search was narrowed down to the topics of cosmic rays, planetary physics, and solar-terrestrial relationships. During the refinement, the search was directed to ensure that the meso- and micro-topics were related to space sciences, excluding, to the extent possible, topics related to astrophysics.

Once the final databases were available, their analysis began using the Bibliometrix tool (Aria and Cuccurullo, 2017). The drawback of Blibliometrix is that the display of results is not as clear as in the Biblioshiny application, which provides a web interface for Bibliometrix.

Biblioshiny allows the results to be viewed through a variety of maps, whose parameters can be easily modified. Furthermore, more complex mappings and networks can be created, which is why this tool was chosen (Moral-Muñoz, 2020). The disadvantage is that, when generating a result, the parameters are not saved, so they must be set from the

Table 3. Levels of information in Biblioshiny.

Analysis level	Element	Description
General Description	Main information	The most relevant parameters: • number of documents, • annual growth percentage, • number of co-authors by document • percentage of international coauthorship.
Authors	Most productive authors over time	Authors productivity is measured in terms of number of publications and total citations per year.
	Production by affiliations over time	It shows document production by affiliation.
	Multiple Country Publications (MCP)	This analysis calculates the proportion of articles in which there is at least one author with an affiliation in a country other than that of the corresponding author.
Documents	Keywords cloud	It shows a visual representation of the most frequent keywords in the analyzed databases.

Table taken from the Aleidi Nicolás Pablo MhD thesis.

beginning to avoid unwanted changes, so in this case, the default values were used.

Using Biblioshiny, information was obtained on three levels of database analysis: authors, sources, and documents. Several elements are derived from these, which are described in Table 3. Subsequently, an analysis was conducted according to three knowledge structures: conceptual, intellectual, and social, explained in Table 4. The conceptual structure represents the relationship between concepts or words used in the database's publications. The intellectual structure shows how different authors cite each other or how they manage references. The social structure represents how authors collaborate. Tables 3 and 4 show the Biblioshiny categories used for this study. In the case of source analysis, although results were obtained for each query in the four countries analyzed, the results were found to be highly similar. Since they are not of major relevance to this study, it was decided not to display them in the results section.

Limitations

For each line of research, 14 elements (plots, maps and networks) were generated but, due to the large amount of information obtained, only the most representative results are shown in this paper. A more complete overview will be found in Aleidi Nicolás Pablo's MhD. thesis (*in progress*).

Furthermore, the purpose of this article is to show a regional overview of space sciences research in Latin America, focusing on Mexico, Brazil, Chile, and Argentina. Therefore, a more detailed analysis of sources and authors could be the subject of another article since the information is extensive and cannot be fully covered in a single paper.

Table 4. Knowledge structures in Biblioshiny.

Knowledge Structures	Element	Description
Conceptual	Thematic map	Plot whose axes are a function of the centrality and density. Centrality is a measure of the theme´s relevance. Density represents its development.
	Co-ocurrence network	Identify research trends and relationships between concepts.
	Thematic evolution	It shows the thematic change over time within a specific research field using an alluvial plot.
Intellectual	Co-citations network	A co-citation occurs when two documents are cited in a third document.
	Historiography	It shows a historical path that identifies the core of authors cited.
Social	Collaboration network	This network identify groups of authors, influential authors, hidden communities of authors, as well as relevant institutions in a specific research field.
	Collaboration map	This map shows the pattern of collaboration at international level.

Table taken from the Aleidi Nicolás Pablo MhD thesis.

Table 5. Relevant parameters of the bibliometric analysis for solar physics.

Country	Documents	Annual growth percentage	Co-authorship by document	International co-authorship percentage
Mexico	323	2.05	7.24	56.97
Argentina	507	5.00	5.47	72.78
Brazil	927	3.89	8.49	62.46
Chile	295	6.73	15.30	84.07

3. Results

In this section, the bibliometric results obtained for Brazil, Argentina, Chile and Mexico are presented, based on the following structure,

a) Table with relevant parameters (number of documents analyzed, annual growth percentage, number of co-authors per document, and international co-authorship percentage).
b) Authorship analysis (most productive authors over time, production by affiliations and Multiple Country Publications (MCP))
c) Documental analysis (keyword clouds)
d) Analysis per structures of knowledge (conceptual, intellectual and social).

All results are presented sequentially (from a) to d)), according to the relevant parameters of the five research lines: solar physics, magnetospheric physics, cosmic rays physics, solar-terrestrial relationships, and planetary physics. Only tables and figures more representatives are shown in this paper, because of the large amount of information.

3.1 Solar Physics

3.1.1 Table with relevant parameters

In table 5, it is possible to see that Mexico has the lowest rate of decrease, while Chile has the highest rate of growth.

3.1.2 Authorship analysis

This analysis shows that Brazil has a very large number of authors who have carried out constant scientific work in solar physics, followed by Argentina. Mexico does not show any growth in the analysis period (20 years), while Chile has not been very productive in this research area, in recent years. Figures 1, 2, 3 and 4 show the temporal author´s production from the four countries analyzed.

The production by affiliation indicates that there is a parallel behavior between Argentina, Chile, and Brazil, while the dominant affiliation in Mexico is UNAM. Respect to Multiple Country Publications (MPC), Mexico has the lowest weighting percentage (MPC) whereas Chile has the highest one.

3.1.3 Documental analysis

This analysis shows the most frequently used terms in the titles, abstracts, and keywords of the publications studied in this paper. These concepts were *solar* and *model* as it is seen in Figure 5, according to the Keywords analysis.

The results indicate that the term, *model* is a highly representative term for Argentina, Brazil and Mexico, while for Chile, the terms *photometry* and *spectroscopy* are more relevant in the documents analyzed. A possible explanation related to this result is that Chile does more observational research since this country has a large number of astronomical observatories where many researchers work.

3.1.4 Analysis per structures of knowledge

The results of this subsection are shown in Table 6, which contains the results for the conceptual, intellectual, and social aspects.

3.2 Cosmic Rays physics

3.2.1 Table with relevant parameters

Table 7 contains the relevant parameters for cosmic rays physics. In this table is observed that Argentina has not any growth and Chile has a very small database in the 20 years period. At the same time, Brazil and Mexico have lower annual development than Chile.

3.2.2 Authorship analysis

This analysis shows that Brazil and Mexico continuously published in the 20 years period while Brazil had a low productivity as well as Argentina. In particular, Argentina had a small number of citations while Mexico shows a relevant result because it had a group of authors with highly cited articles, in 2018.

The productivity by affiliation indicates that Argentina, Brazil, and Chile present similarities in their different institutions, whereas the UNAM has the highest number of publications in Mexico. Table 8 shows the most relevant affiliations for cosmic rays physics in each country analyzed.

The results for MCP show that United States had the highest number of articles with at least, one author of a different nationality from that of the corresponding author.

On the other hand, Argentina presented the lowest weighting percentage while Chile had the highest one (100%), (Table 7). However, this result should be taken with caution because Chile has a very small database.

3.2.3 Documental analysis

The keywords analysis indicates that Mexico has a limited number of terms, whereas the other countries present a wide variety of them. In particular, Chile has an important connection

México

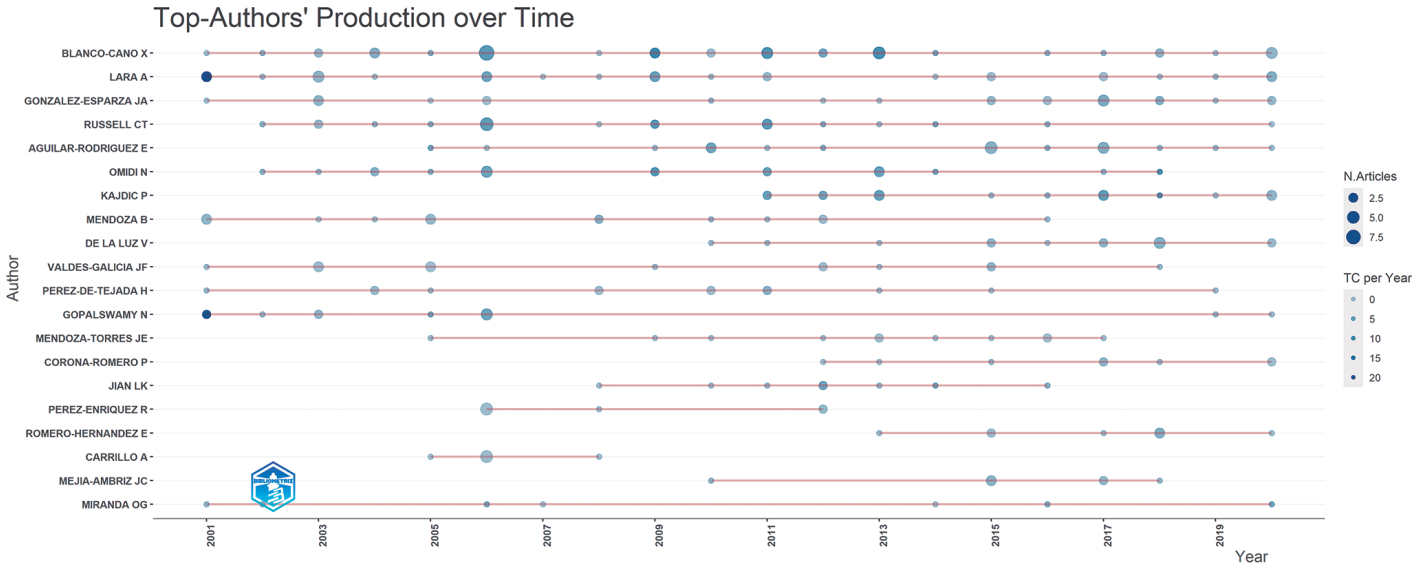

Figure 1. Authorship analysis in solar physics for Mexico. Most productive authors (y axis) vs time. Size of the circles indicates number of articles and color indicates number of citations per year.

Argentina

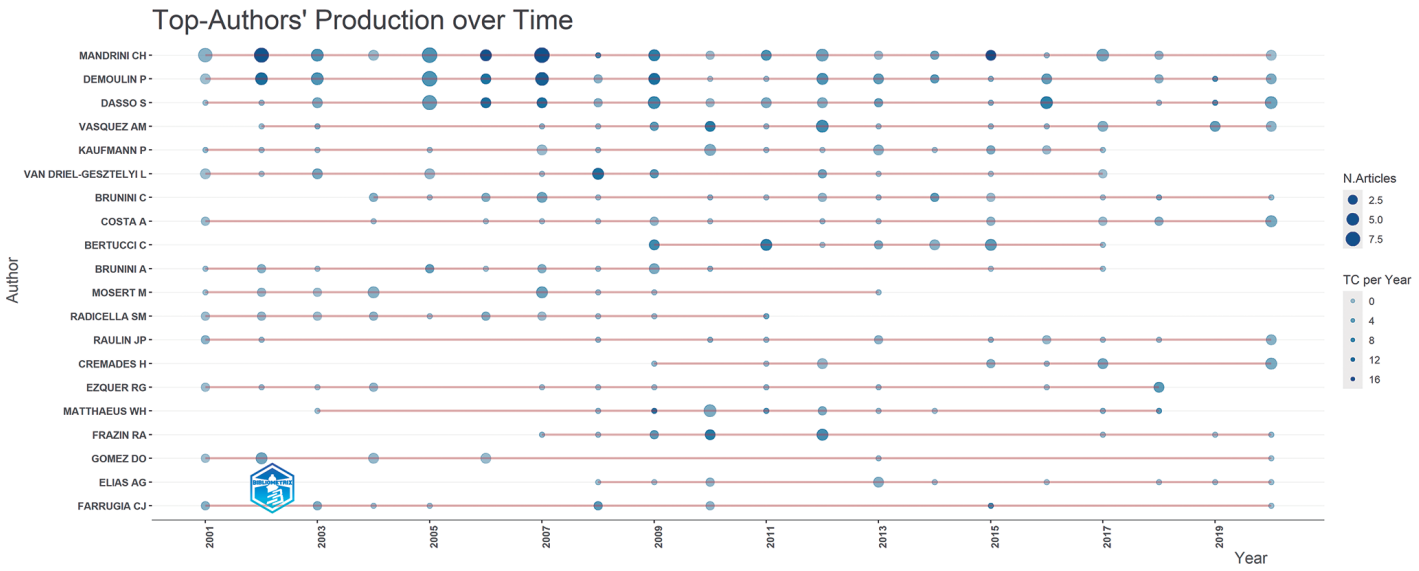

Figure 2. Authorship analysis in solar physics for Argentina. Most productive authors (y axis) vs time. Size of the circles indicates number of articles and color indicates number of citations per year.

Brazil

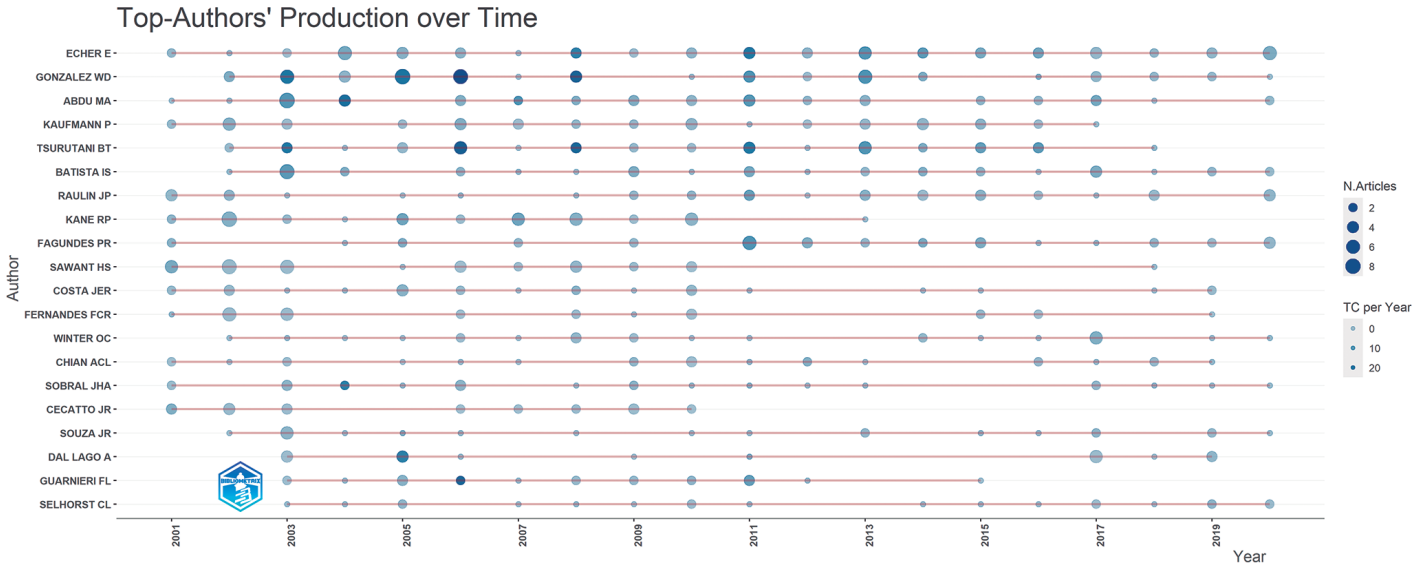

Figure 3. Authorship analysis in solar physics for Brazil. Most productive authors (y axis) vs time. Size of the circles indicates number of articles and color indicates number of citations per year.

Chile

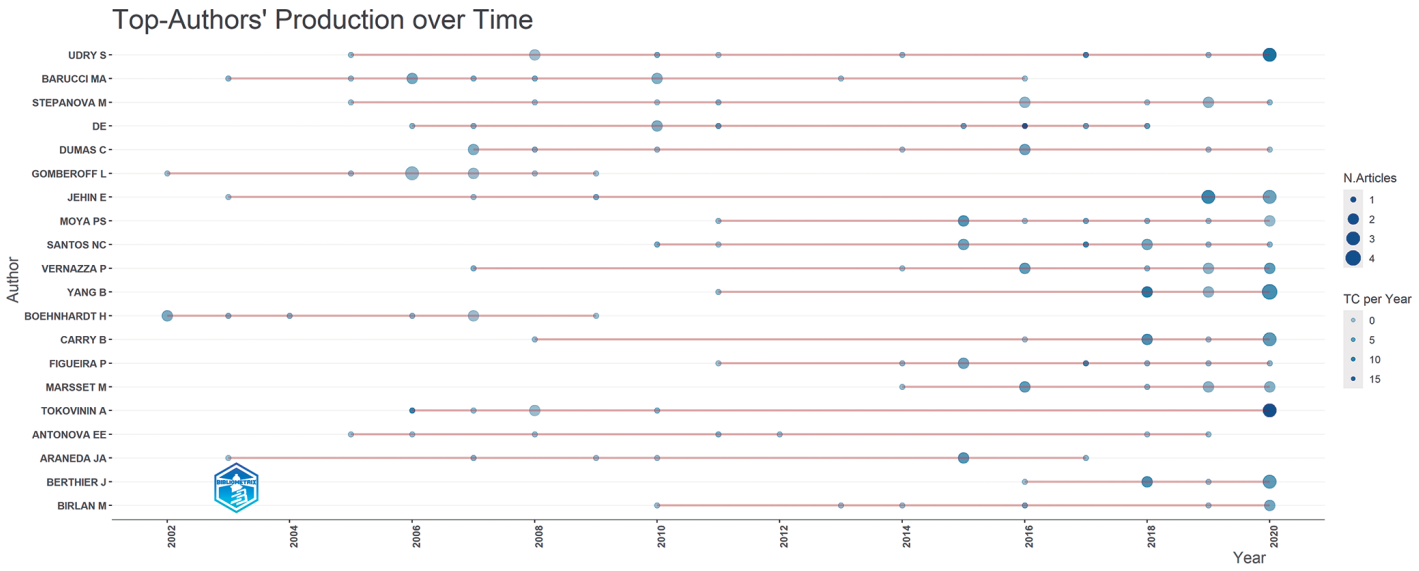

Figure 4. Authorship analysis in solar physics for Chile. Most productive authors (y axis) vs time. Size of the circles indicates number of articles and color indicates number of citations per year.

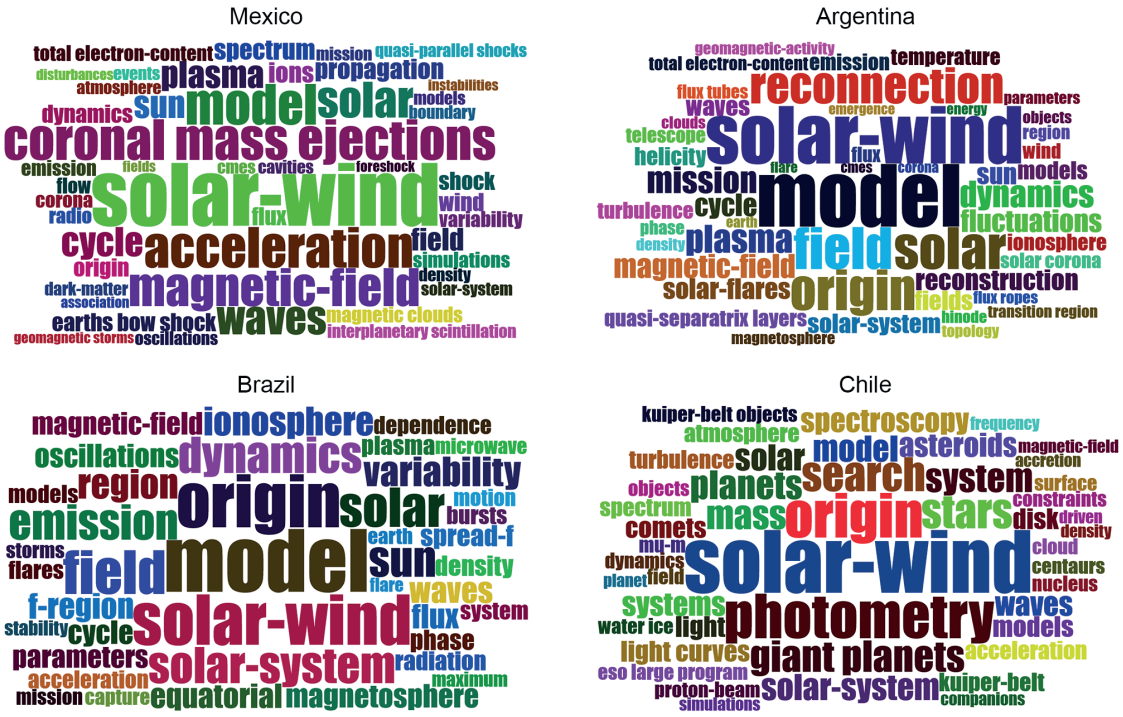

Figure 5. Keywords cloud in solar physics.

Table 6. Knowledge structures in Biblioshiny for solar physics.

Knowledge Structures	Element	Result
Conceptual	Thematic map	Mexico has a greater number of well-defined, highly developed, and relevant motor themes than the other countries (Argentina, Brazil and Chile), as well as this country has also developed basic themes but in some cases, they have a high degree of development but with little relevance. Additionally there are also emerging and declining themes in Mexico. Argentina and Brazil do not present diversity in themes, while Chile has a greater variety of them.
	Co-ocurrence network	*Coronal mass ejections, solar wind, model, and magnetic field* are terms with a highest frequency in Mexico. The *terms solar wind, coronal mass ejections, and model*, appear in many papers, published by Brazil and Argentina. The term solar wind appears mainly in Chilean works although the term photometry has a relevant presence.
	Thematic evolution	Argentina and Brazil have developed a wide ranging thematic in particular periods, whereas Chile and Mexico have not had meaningful changes over time.
Intellectual	Co-citations network	Argentina shows an intense co-citation pattern while in the other countries under study, the patterns are weak, it suggests that the different research groups do not cite between them.
	Historiography	Mexico has only one thematic research path with its own core of authors, while Argentina has three well-defined paths.
Social	Collaboration network	The four countries have few clusters with little interaction between them. In particular, the clusters in Chile are very united.
	Collaboration map	Brazil, Chile, Argentina and Mexico have a close collaboration with United States of America (USA).
		In particular, Chile and Brazil have an intense collaboration pattern with USA, and have collaborations with Europe and Asia as well. Mexico has a poorest international collaboration with the rest of the world

Table taken from the Aleidi Nicolás Pablo MhD thesis.

Table 7. Relevant parameters of the bibliometric analysis for cosmic rays physics.

Country	Documents	Annual growth percentage	Co-authorship by document	International co-authorship percentage
Mexico	53	5.95	14.80	80.00
Argentina	29	0.00	10.10	79.31
Brazil	110	3.72	19.20	76.36
Chile	12	8.16	60.20	100.00

Table 8. Most relevant affiliations for cosmic rays physics.

Argentina		Brazil		Chile		Mexico	
Affiliation	Articles	Affiliation	Articles	Affiliation	Articles	Affiliation	Articles
UNIV BUENOS AIRES	12	UNIV SAO PAULO	37	STANFORD UNIV	9	UNIV NACL AUTONOMA MEXICO	84
UNIV DELAWARE	10	INST NACL PESQUISAS ESPACIAIS	32	PONTIFICIA UNIV CATOLICA CHILE	8	UNIV MARYLAND	18
UNIV CALIF LOS ANGELES	8	UNIV DELAWARE	21	UNIV CALIF SANTA CRUZ	6	NORTH WEST UNIV	13
GODDARD SPACE FLIGHT CTR	7	UNIV WISCONSIN	20	UNIV MARYLAND	6	NAGOYA UNIV	9
NATL UNIV LA PLATA	7	UNIV ESTADUAL CAMPINAS	17	HIROSHIMA UNIV	5	PENN STATE UNIV	8
INST ASTRON AND FIS ESPACIO	6	SHINSHU UNIV	16	UNIV TRIESTE	5	UNIV CALIF SANTA CRUZ	8
UNIV NACL CUYO	4	UNIV FED FLUMINENSE	15	UNIV UDINE	5	BENEMERITA UNIV AUTONOMA PUEBLA	7
UNIV NACL LA PLATA	4	UNIV MINNESOTA	14	CLEMSON UNIV	4	INST NACL ASTROFIS OPT AND ELECTR	7
CTR ATOM BARILOCHE	3	FERMILAB NATL ACCELERATOR LAB	13	GODDARD SPACE FLIGHT CTR	4	CHUBU UNIV	5
HARVARD SMITHSONIAN CTR ASTROPHYS	3	NATL INST SPACE RES	12	STOCKHOLM UNIV	4	GODDARD SPACE FLIGHT CTR	5
STANFORD UNIV	3	SCHUCH	12	UNIV INNSBRUCK	4	INST POLITECN NACL	5
UNIV MARYLAND	3	ARGONNE NATL LAB	10	UNIV WISCONSIN	4	LOS ALAMOS NATL LAB	5
UNIV MARYLAND BALTIMORE CTY	3	HARVARD UNIV	10	YALE UNIV	4	UNIV NEW MEXICO	5
UNIV PARIS SACLAY	3	NAGOYA UNIV	10	CRESST	3	UNIV ROCHESTER	5
UNIV SAO PAULO	3	NATL INST SPACE RES INPE	10	DIV SPACE SCI	3	CARLETON UNIV	4
UNIV SCI AND TECHNOL CHINA	3	UNIV TASMANIA	10	EAST CHINA UNIV SCI AND TECHNOL	3	HARVARD SMITHSONIAN CTR ASTROPHYS	4
CAS CTR EXCELLENCE COMPARAT PLANETOL	2	UNIV FED RIO GRANDE DO NORTE	9	ECOLE POLYTECH	3	MICHIGAN TECHNOL UNIV	4
CIUDAD UNIV	2	INDIANA UNIV	8	GEORGE MASON UNIV	3	SANTA CRUZ INST PARTICLE PHYS	4
CNRS	2	STANFORD UNIV	8	INST HIGH ENERGY PHYS	3	UNIV AUTONOMA CHIAPAS	4
CTR ATOM BARILOCHE CNEA CONICET	2	TUFTS UNIV	8	KTH ROYAL INST TECHNOL	3	UNIV AUTONOMA ESTADO HIDALGO	4

with the term, *galaxies* but almost none, with the *Solar System* terms (Figure 5).

3.2.4 Analysis per structures of knowledge

The knowledge structures for cosmic rays physics are shown in Table 9 and the word co-occurrence network in this field is presented in Figure 6. The colors of the word co-occurrence network represent the clusters to which each word belongs. The size of a node in the network represents the number of times the term appears in the documents analyzed. The size of an edge represents the number of times the two words linked by the edge appear in a document, for all the documents. Each cluster can be seen as a *topic*. The words in this network come from author keywords, Keywords Plus, or terms extracted from titles and abstracts in a document.

3.3 Magnetospheric physics

3.3.1 Table with relevant parameters

The relevant parameters appear in Table 10. This table shows that Brazil has the largest database, while Argentina has the highest annual growth rate respect to the other countries. In these countries, the co-authorship per document fluctuates between 6 and 7 authors, and most co-authors are foreigners.

3.3.2 Authorship analysis

The results obtained from this analysis show that Brazil has some authors whose productivity has been consistent throughout the 20 years period. Argentina shows a period of increased productivity between 2008 and 2013, whereas productivity in Chile began to increase from 2015 to the present. In Mexico, there has not been any development in this area of knowledge.

The affiliations analysis shows that Argentina, Brazil, and Chile contribute significantly to each other, while in Mexico, UNAM is the main affiliation. Another important result is that Mexico does not participate significantly in magnetospheric physics research with other countries, which is reflected in a very low weighting percentage of MCP.

3.3.3 Documental analysis

According to the keyword analysis, there is a weak relationship between keywords and search topics in Mexico (Table 1);

Table 9. Knowledge structures in Biblioshiny for cosmic rays physics.

Knowledge Structures	Element	Results
Conceptual	Thematic map	Mexico exhibits well-defined motor themes related to cosmic rays, although there are no basic themes or themes with a high degree of development. Brazil and Argentina have not only motor and basic themes, but also some emerging or in declining themes. Both countries have few themes that have a high level of development. The results also show that Chile has few themes of great relevance and development.
	Co-ocurrence network	The network of occurrences in Mexico and Brazil is not very extensive, although Mexico has some recurring terms. The term cosmic rays is the recurring term in Argentina and Chile and it is probably related to astronomical observatories in Chile (Figure 3).
	Thematic evolution	Thematic evolution is nonexistent in Argentina and poorly consistent in Brazil and Mexico. Since the Chilean database is very limited, there are no results.
Intellectual	Co-citations network	In general, there are no big clusters in all countries studied, even though the Chilean clusters are more integrated.
	Historiography	Mexico and Brazil have paths of research developed throughout the analysis period, while Argentina presents short paths of research. There are no results for Chile, probably because the data are insufficient or simply nonexistent.
Social	Collaboration network	Mexico and Chile have two principal clusters while Brazil and Argentina have isolated clusters. In all cases, there are dominant clusters.
	Collaboration map	Argentina has the smallest collaboration pattern compared to the other countries. Brazil has a very extensive collaboration pattern, and only Mexico collaborates with some African countries. Mexico and Brazil have no collaboration at all, and USA is the main collaborator of the four Latin American countries studied.

Table taken from the Aleidi Nicolás Pablo MhD thesis.

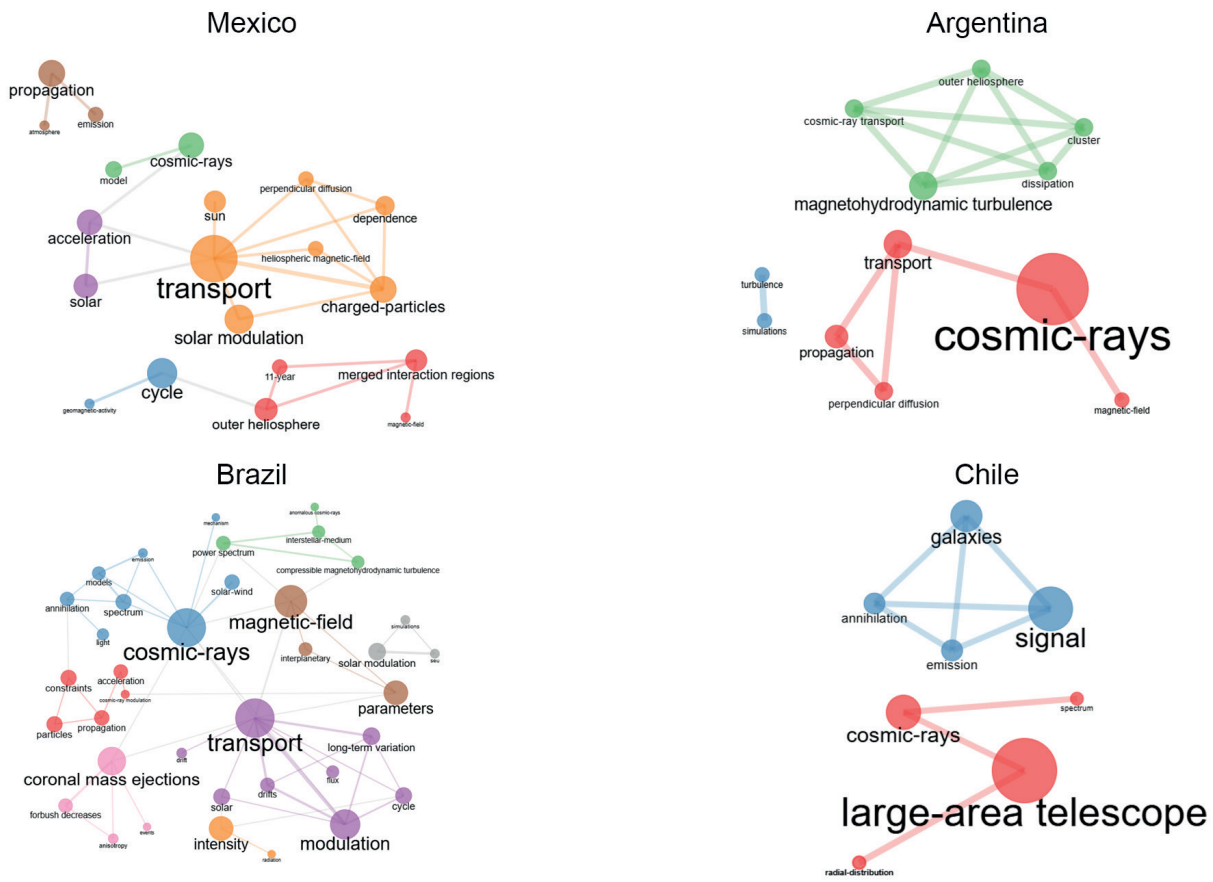

Figure 6. Co-occurrence network in cosmic rays physics for: Mexico, Argentina, Brazil and Chile. The colors of the subnetworks represent the clusters to which each word belongs. Size of a node represents the number of times the term appears in the documents analyzed. Size of an edge represents the number of times the two words linked by the edge appear in a document, for all the documents.

Table 10. Relevant parameters of the bibliometric analysis for magnetospheric physics.

Country	Documents	Annual growth percentage	Co-authorship by document	International co-authorship percentage
Mexico	37	1.53	7.14	72.97
Argentina	61	8.84	6.57	83.61
Brazil	125	1.53	6.63	79.20
Chile	68	2.16	6.01	86.76

while in Brazil and Argentina, there is a strong relationship between them (Table 1). In the case of Chile, there is a connection with terms related to *stellar physics*, which are not part of this study and were not included in this paper.

3.3.4 Analysis per structures of knowledge

In this subsection the knowledge structures for magnetospheric physics are shown in Table 11. Figures 7, 8, 9 and 10 show the thematic map for the analyzed countries and the collaboration network of this research field is shown in Figures 11, 12, 13 and 14 respectively.

In Figures 7, 8, 9 and 10, each bubble represents a network cluster. The bubble names are words, belonging in the cluster, with the higher occurrence value. The bubble size is proportional to the cluster word occurrences. The bubble horizontal position is set according to the cluster Callon centrality and the vertical position to the Callon density. The Callon centrality measures how strongly a cluster of keywords is connected to other clusters. It represents the importance or relevance of a theme within the

Table 11. Knowledge structures in Biblioshiny for magnetospheric physics.

Knowledge Structures	Element	Results
Conceptual	Thematic map	Brazil, Argentina, and Chile present basic, emerging, or declining themes, except for Mexico, where no development of any of the themes is observed. Brazil and Argentina present more defined structures in the four quadrants, while Chile has not consolidated in some themes due to its recent boom in magnetospheric physics, although it has a considerable number of motor themes (Figure 4).
	Co-ocurrence network	Brazil has a small network, but with a greater diversity of terms compared to Mexico's network.
	Thematic evolution	Mexico has not evolved thematically. This result is also evident in the thematic map. The thematic evolution in Brazil, Chile, and Argentina shows changes, although they are small.
Intellectual	Co-citations network	The co-citation network in Brazil is broad, while the network in Argentina, Mexico, and Chile shows that only researchers belonging to the same cluster cite each other. In general, the co-citation network is weak in all cases.
	Historiography	In Argentina, Chile, and Brazil, there are paths of research generated with documents from the analyzed databases. They are highly developed and show great diversity. It is unclear whether these paths of research are very small or nonexistent in Mexico.
Social	Collaboration network	For all cases, collaboration networks show that there is little collaboration between working groups as well as greater isolation between them (Figure 5).
	Collaboration map	Brazil shows a significant pattern of collaboration, while Mexico has the least significant pattern compared to the other three countries. Argentina, Chile, and Mexico have little collaboration with Asia and Australia; while Brazil and Chile have no collaboration with Mexico.

Table taken from the Aleidi Nicolás Pablo MhD thesis.

overall research field. The Callon density measures the internal cohesion of a cluster, how strongly the keywords within the same cluster are connected to each other (or the development degree) (Callon *et al.*, 1991, 1983).

3.4 Solar-terrestrial relationships

3.4.1 Table with relevant parameters

In this area, the relevant parameters appear in Table 12 where it is observed that Mexico has the lowest annual growth rate respect to the other countries as well as, the lowest percentage of international collaboration. Compared to the others countries, Chile stands out as the country with the biggest growth in this field, the largest number of co-authors per document, and a high rate of international co-authorship.

3.4.2 Authorship analysis

The productivity analysis by authors shows that Brazil is the country with the highest productivity, but with rarely cited works whereas Argentina has a small group of relevant authors and Mexican authors have little relevance in this field.

Chile does not present continuous lines of work in the 20 years period; probably because of it is a field of emerging development in this country.

The production by affiliations has a similar behavior in Mexico and Brazil and they have a dominant institution that leads the productivity. In contrast, there is greater participation among several institutions that contribute to their productivity in Argentina and Chile.

The results related to the MCP indicate that Mexico has the lowest weighting percentage and the published articles have at

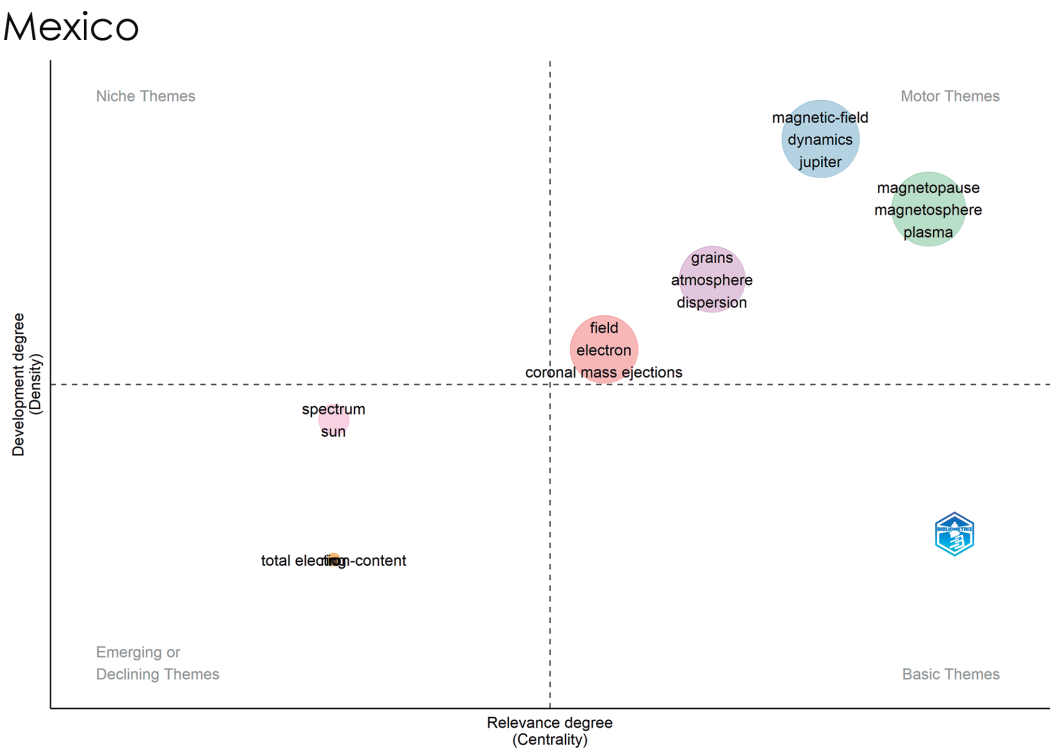

Figure 7. Thematic map of Latin American countries in magnetospheric physics for Mexico. Each bubble represents a network cluster. The bubble names are words belonging in the cluster, with the higher occurrence value. The bubble size is proportional to the cluster word occurrences. The bubble position is set according to the cluster Callon centrality and density.

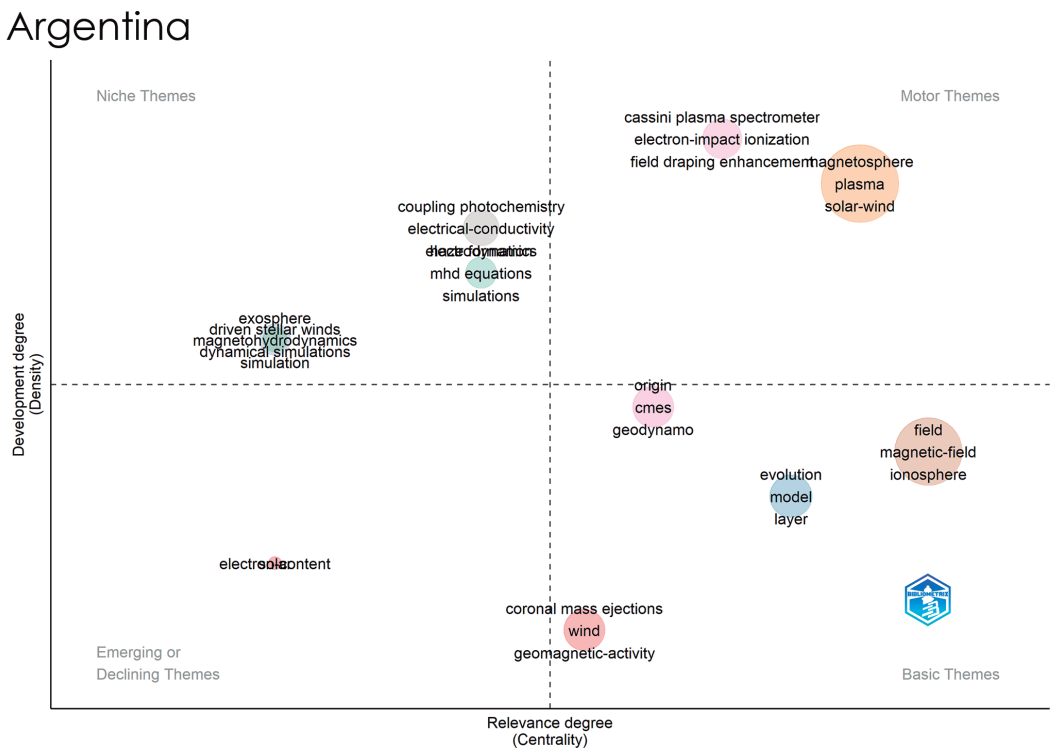

Figure 8. Thematic map of Latin American countries in magnetospheric physics for Argentina. Each bubble represents a network cluster. The bubble names are words belonging in the cluster, with the higher occurrence value. The bubble size is proportional to the cluster word occurrences. The bubble position is set according to the cluster Callon centrality and density.

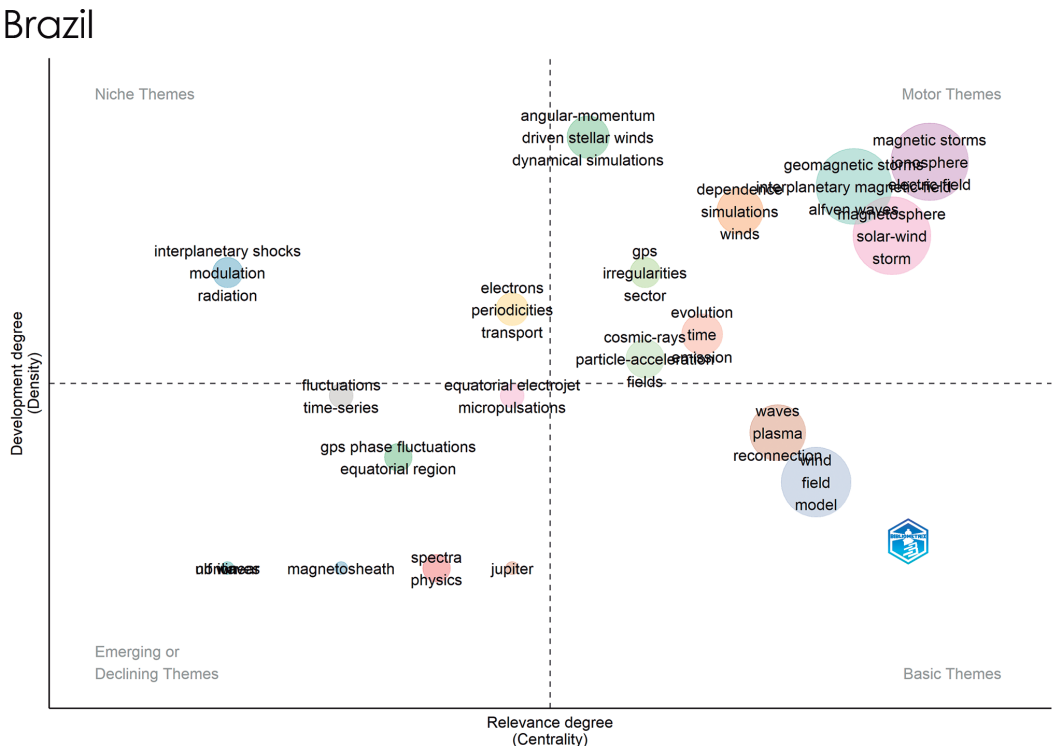

Figure 9. Thematic map of Latin American countries in magnetospheric physics for Brazil. Each bubble represents a network cluster. The bubble names are words belonging in the cluster, with the higher occurrence value. The bubble size is proportional to the cluster word occurrences. The bubble position

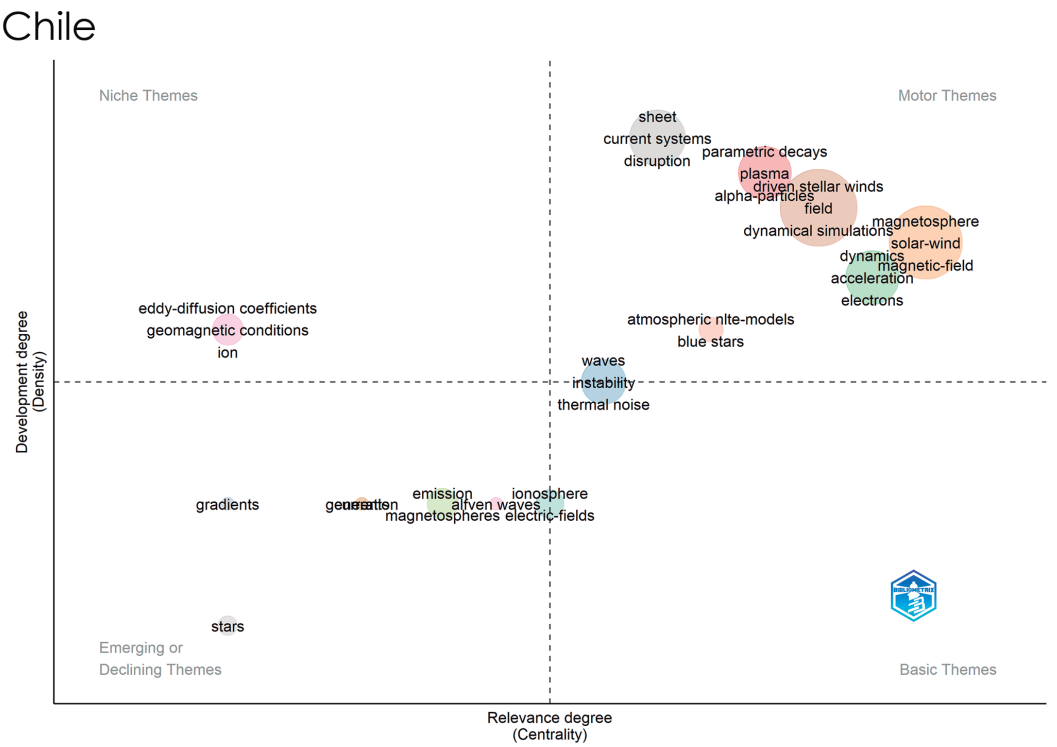

Figure 10. Thematic map of Latin American countries in magnetospheric physics for Chile. Each bubble represents a network cluster. The bubble names are words belonging in the cluster, with the higher occurrence value. The bubble size is proportional to the cluster word occurrences. The bubble position is set according to the cluster Callon centrality and density.

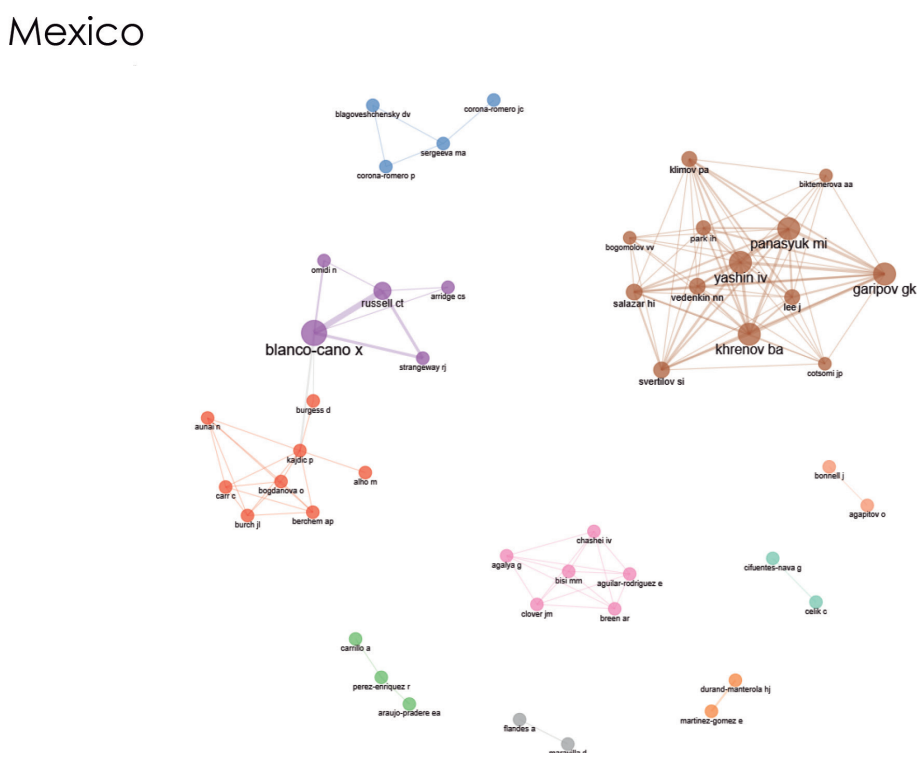

Figure 11. Collaboration network for magnetospheric physics for México. Nodes in the networks are authors and edges are co-authorships. Colors of the subnetworks highlight the clusters to which each author belongs.

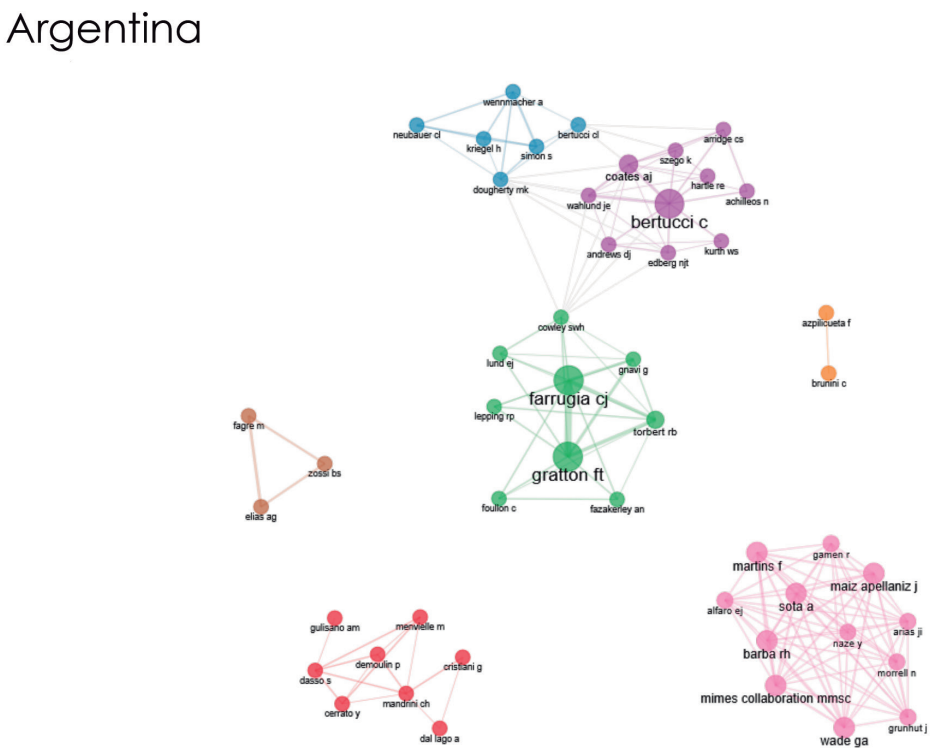

Figure 12. Collaboration network for magnetospheric physics for Argentina. Nodes in the networks are authors and edges are co-authorships. Colors of the subnetworks highlight the clusters to which each author belongs.

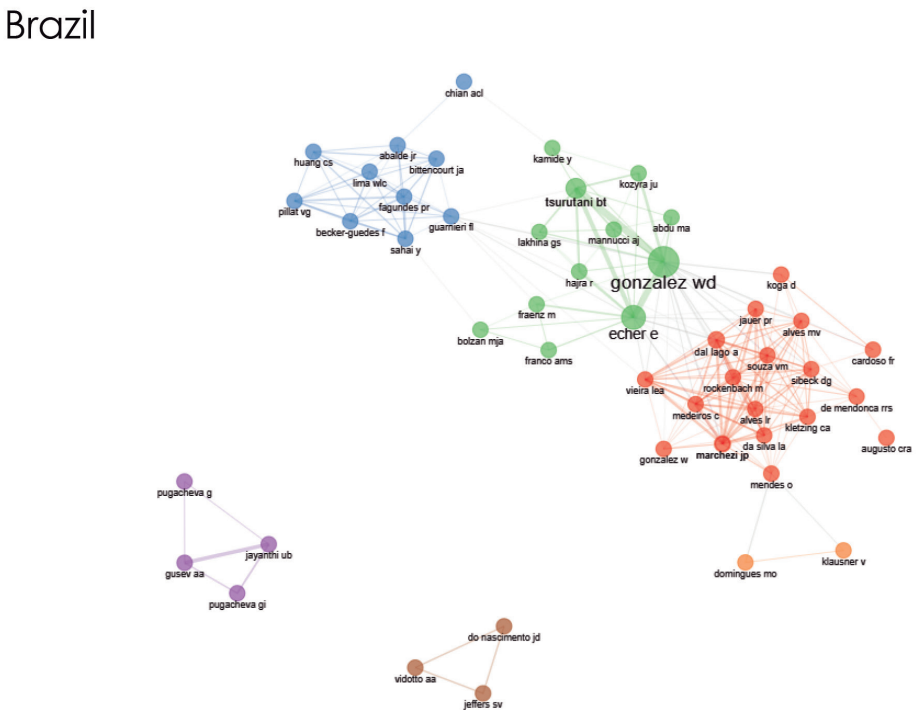

Figure 13. Collaboration network for magnetospheric physics for Brazil. Nodes in the networks are authors and edges are co-authorships. Colors of the subnetworks highlight the clusters to which each author belongs.

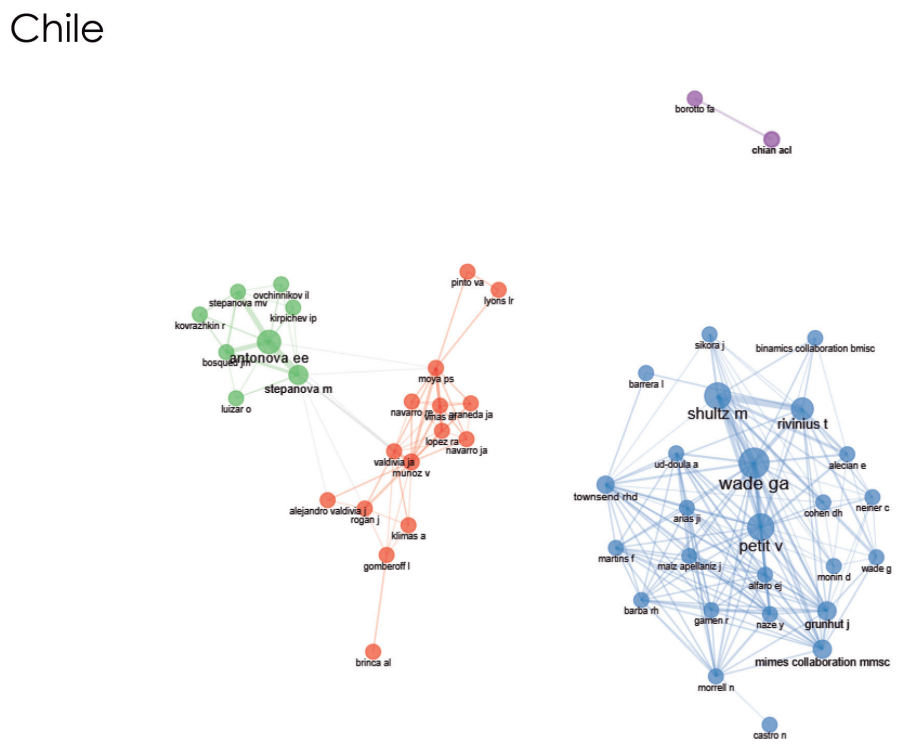

Figure 14. Collaboration network for magnetospheric physics for Chile. Nodes in the networks are authors and edges are co-authorships. Colors of the subnetworks highlight the clusters to which each author belongs.

Table 12. Relevant parameters of the bibliometric analysis for solar-terrestrial relationships physics.

Country	Documents	Annual growth percentage	Co-authorship by document	International co-authorship percentage
Mexico	116	1.53	7.04	55.17
Argentina	200	7.91	5.96	72.00
Brazil	406	6.54	6.57	64.53
Chile	92	12.26	16.00	90.22

least, one foreign author who is not the corresponding author. In Chile, although the weighting percentage of MCPs is significant from the statistical point of view, the authors of most publications are affiliated to United States institutions.

Table 13 shows the most relevant countries by corresponding author in the field of solar-terrestrial relationships for the countries analyzed.

3.4.3 Documental analysis

The analysis of keywords indicates that the terms *evolution* and *variability* are related to events of solar-terrestrial relationships however, concepts related to *solar activity* are also appreciated.

3.4.4 Analysis per structures of knowledge

For this research field, the knowledge structures for solar-terrestrial relationships are shown in Table 14, and the co-citations network appears in Figures 15, 16, 17 and 18.

3.5 Planetary physics

3.5.1 Table with relevant parameters

For this query, the most relevant parameters are presented in Table 15. The results show that Chile has the highest rates of annual growth percentage, number of coauthors per document, and international co-authorship. Mexico and Argentina have a similar growth rate, while Brazil has the lowest rate of all. At the same time, Mexico, Argentina, and Brazil present similar results for the concepts: coauthors per document and international co-authorship.

3.5.2 Authorship analysis

The results show that Mexico is the country with the lowest productivity in the 20 years period respect to the other countries whereas Argentina has a higher productivity than Mexico, but lesser than Chile and Brazil, which is the country with most productivity in this field. Table 16 shows the most relevant authors in planetary physics for the countries analyzed.

The productivity by affiliation indicates that Mexico has a leading institution in scientific production; Brazil has two, while Argentina and Chile have a more equitable distribution, between different institutions. The most representative institutions in Argentina, are national, while in Chile, most of them are foreigners.

Respect to MCP weighting percentage, Chile has a high MPC although most publications have authors affiliated to United States institutions. In the rest of the countries, the weighting percentage is approximately 30%.

3.5.3 Documental analysis

From the keywords analysis, the results indicate that Argentina and Brazil have several terms in common; this may be due to the fact that there is a high degree of collaboration between these countries. The results also show that there are terms associated with *observational techniques* in Chile, Argentina, and Brazil, possibly linked to the observational work carried out in these countries. Mexico does not present this terminology, it could be inferred that only theoretical work is carried out in this country.

3.5.4 Analysis per structures of knowledge

In this section, the knowledge structures for planetary physics are shown in Table 17 and a collaboration map of the countries analyzed is presented in Figure 19.

4. Discussion

This paper presents, for the first time, a bibliometric study of five areas of space sciences developed at the Institute of Geophysics of UNAM. The results obtained are not only important for understanding the progress of space sciences in Latin America but could also provide information on the future of this field of knowledge in the region.

Based on the initial analysis, countries that conduct research in space sciences were identified, and it was found that space

Table 13. Most relevant countries by corresponding author for solar-terrestrial relationships.

Argentina				Brazil				Chile				Mexico			
Country	**Articles**	**SCP**	**MCP**	**Country**	**Articles**	**SCP**	**MCP**	**Country**	**Articles**	**SCP**	**MCP**	**Country**	**Articles**	**SCP**	**MCP**
ARGENTINA	104	55	49	BRAZIL	275	144	131	USA	23	0	23	MEXICO	78	51	27
BRAZIL	21	0	21	USA	53	0	53	CHILE	21	9	12	USA	16	0	16
FRANCE	17	0	17	FRANCE	16	0	16	FRANCE	10	0	10	FRANCE	3	0	3
USA	17	0	17	INDIA	9	0	9	GERMANY	6	0	6	ANTIGUA	2	1	1
UNITED KINGDOM	13	0	13	ITALY	8	0	8	BRAZIL	4	0	4	JAPAN	2	0	2
ITALY	5	0	5	CHINA	7	0	7	CANADA	3	0	3	NETHERLANDS	2	0	2
BELGIUM	3	0	3	UNITED KINGDOM	6	0	6	ITALY	3	0	3	RUSSIA	2	0	2
CZECH REPUBLIC	3	0	3	GERMANY	5	0	5	SPAIN	3	0	3	SPAIN	2	0	2
GERMANY	3	0	3	RUSSIA	4	0	4	UNITED KINGDOM	3	0	3	SWEDEN	2	0	2
COLOMBIA	2	0	2	CHILE	3	0	3	BELGIUM	2	0	2	ARGENTINA	1	0	1
NETHERLANDS	2	0	2	AUSTRALIA	2	0	2	IRELAND	2	0	2	BRAZIL	1	0	1
SPAIN	2	0	2	CANADA	2	0	2	JAPAN	2	0	2	CHINA	1	0	1
URUGUAY	2	0	2	SPAIN	2	0	2	PORTUGAL	2	0	2	COSTA RICA	1	0	1

SCP: Single Country Publications
MCP: Multiple Country Publications

sciences are not developed in most Latin American countries. This fact impacts the development and progress of the different areas of research, probably due to the following factors: a) in most Latin American countries, there are no graduate programs related to this field of knowledge; b) countries invest more in training professionals in other fields; c) there is no interest in space sciences in most of these countries, probably associated to development policies, among other factors.

Bibliometric results also indicate that in the area of solar physics, Chile is the country with the greatest scientific development compared to the others three countries, during the 20-years period . In contrast, Mexico has a low productivity in the number of published articles, despite the fact that solar studies continue to be conducted in Mexico, especially those related to the analysis of data from recent space missions such as the Parker Solar Probe. This result also reflects that the research conducted in Mexico is primarily carried out at UNAM.

The four Latin American countries have a strong scientific dependence on United States, likely due to the fact that, in the last five decades, United States has developed space technology to conduct in situ, studies of the inner solar system particularly, on the Sun, obtaining extensive data that have allowed to understand and modeling many facets of solar phenomenology as well as observatories at ground level, to observe our star at different wavelengths. This fact has led Latin American researchers to seek international collaborations with American colleagues generating a scientific dependence between them.

At present, American collaboration is essential for Latin American countries involved in this study.

In the area of magnetospheric physics, Brazil is the country with the highest productivity (125 items) compared to the other three countries. Chile has the highest rate of international scientific collaboration and Mexico is the country with practically no development in this area. A possible connection with this result may be related with the fact that several countries conduct geomagnetic research not only on Earth but also on other magnetized bodies in the Solar System, overlapping the field of work of space sciences and probably influencing the low development of magnetospheric physics in Latin America.

The bibliometric results in cosmic rays physics, show that this area has been little developed in Chile and Brazil whereas the productivity in Argentina and Mexico is low in the period analyzed, despite the fact that Argentina has the Pierre Auger Observatory and Mexico has two cosmic ray observatories and both countries have developed motor themes.

Furthermore, the co-authors affiliations are primarily linked to United States, indicating a strong dependence on United States collaboration for publication in these Latin American countries.

Table 14. Knowledge structures in Biblioshiny for solar-terrestrial relationships.

Knowledge Structures	Element	Results
Conceptual	Thematic map	Argentina and Chile have several motor, relevant, and highly developed themes, some basic themes, and others in development while Mexico and Brazil have not relevant thematic development.
	Co-ocurrence network	Mexico and Brazil have more clusters than Argentina and Chile. However, in Chile, there are clusters that are less coincident with the rest of the countries under study.
	Thematic evolution	Argentina, Brazil, Chile and Mexico showed no thematic evolution during the period analyzed.
Intellectual	Co-citations network	Argentina has two principal clusters, unlike the rest of the countries that have several small and isolated clusters (Figure 6).
	Historiography	Argentina presents a very articulated research path, in contrast to the rest of the countries that show less developed paths of research.
Social	Collaboration network	Brazil and Chile have more integrated clusters in contrast Argentina and Mexico show several isolated clusters with little connection between them.
	Collaboration map	In all cases, global collaboration is enormous with USA. Chile and Brazil have an intense pattern of collaboration, while Mexico and Argentina have little collaboration with Asian countries. There is not any collaboration between Mexico and Chile and Mexico is the only country that does not collaborate with Australia.

Table taken from the Aleidi Nicolás Pablo MhD thesis.

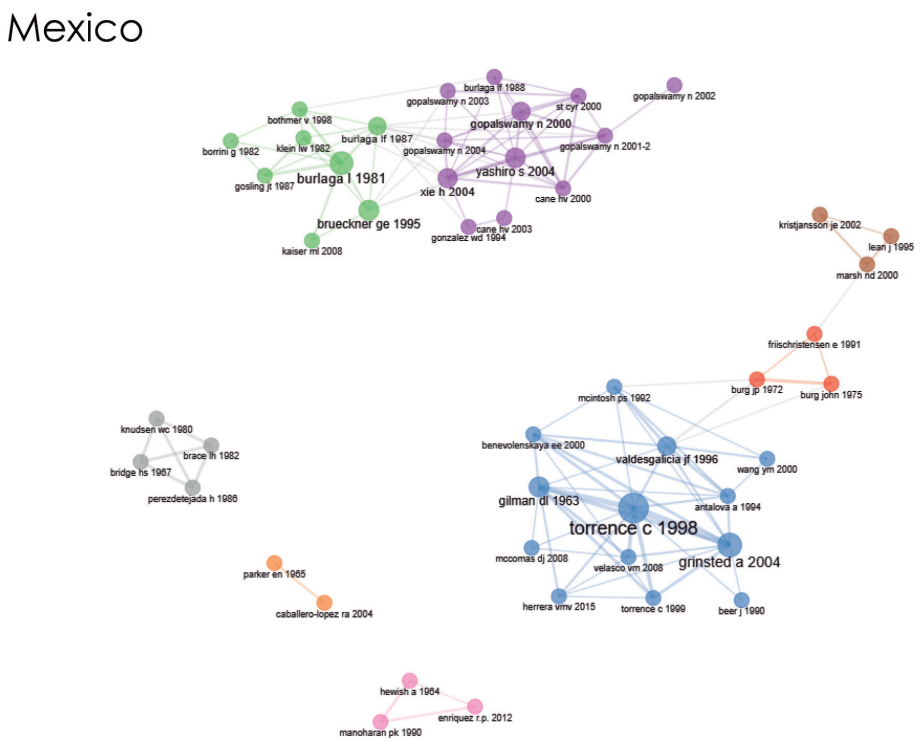

Figure 15. Co-citations related with the intellectual structure in solar-terrestrial relationships physics for Mexico. Nodes represent the most cited documents. Edges represent co-citations in both documents.

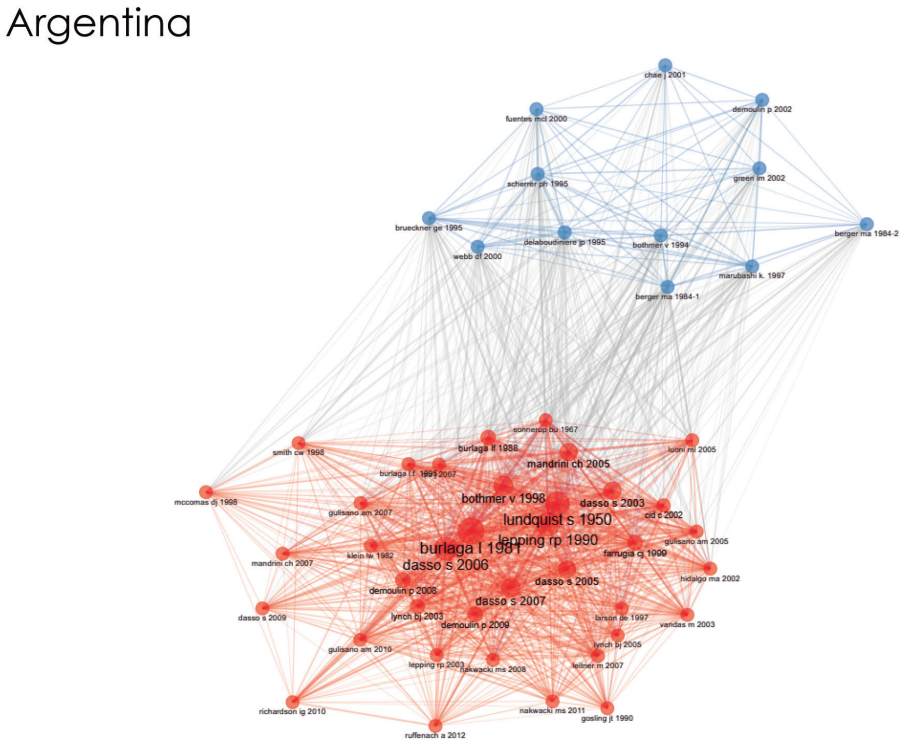

Figure 16. Co-citations related with the intellectual structure in solar-terrestrial relationships physics for Argentina. Nodes represent the most cited documents. Edges represent co-citations in both documents.

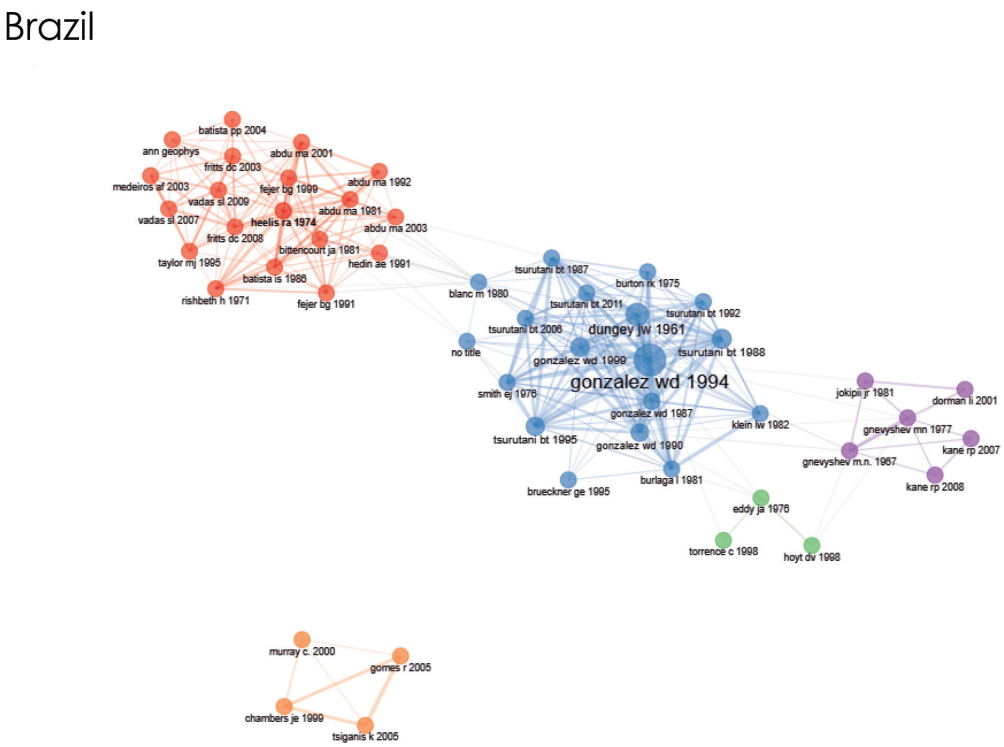

Figure 17. Co-citations related with the intellectual structure in solar-terrestrial relationships physics for Brazil. Nodes represent the most cited documents. Edges represent co-citations in both documents.

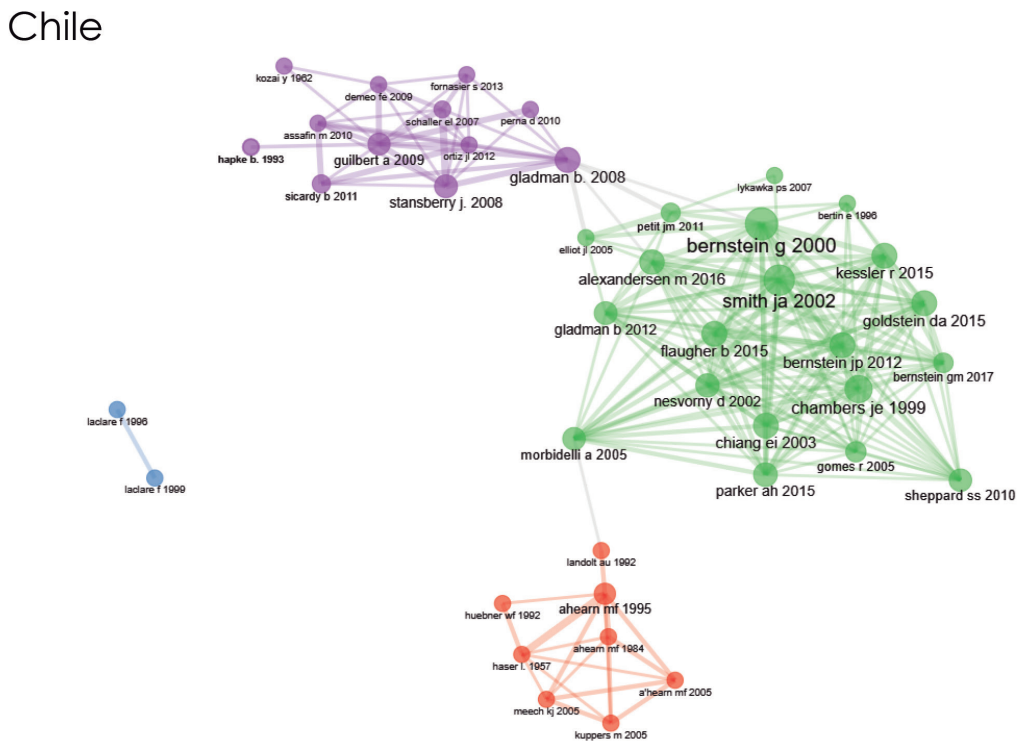

Figure 18. Co-citations related with the intellectual structure in solar-terrestrial relationships physics for Chile. Nodes represent the most cited documents. Edges represent co-citations in both documents.

Table 15. Relevant parameters of the bibliometric analysis for planetary physics.

Country	Documents	Annual growth percentage	Co-authorship by document	International co-authorship percentage
Mexico	112	9.39	7.37	61.61
Argentina	191	9.21	8.76	65.45
Brazil	397	6.44	7.89	63.22
Chile	313	15.58	21.00	94.57

Mexico has a small database compared to Brazil in the area of solar-terrestrial relationships, whereas Chile not only has a smaller database, but also this country has a greater scientific productivity as well as an important international collaboration. The Mexican productivity decreased in recent years and Chile had a boom period between 2007 and 2008. Since 2019, Chile has had a big impact as well as a relevant participation in research projects at international level. This result is related with its high degree of international collaboration because of the numerous scientific consortiums that have been established in that country.

United States is also, the main collaborator of all Latin American countries analyzed in the area of planetary sciences. In particular, Chile has a high degree of foreign collaboration and its scientific production is carried out by authors or co-authors affiliates to foreign institutions. This country experienced a significant increase in productivity since 2009 and becoming much more productive than Argentina, Brazil, and Mexico. Particularly, Mexico has the lowest productivity respect to Argentina, Brazil, and Chile in this area.

All these bibliometric results (publications number, co-citations, affiliations, coauthors, working groups networks, and so on) show, that space sciences in these Latin American countries have had a slow development as well as a strong dependence on United States.

The results clearly show that Chile is the country with a wider international network where foreign institutions and co-authors are involved, the UNAM is the main institution in Mexico, where space sciences are developed and, Argentina, Chile, and Brazil

Table 16. Most relevant authors for planetary physics.

Argentina		Brazil		Chile		Mexico	
Authors	**Articles**	**Authors**	**Articles**	**Authors**	**Articles**	**Authors**	**Articles**
GIL-HUTTON R	21	CARRUBA V	47	JEHIN E	39	FLANDES A	11
BEAUGE C	17	LAZZARO D	39	YANG B	32	BLANCO-CANO X	9
BRANHAM RL	17	NESVORNY D	33	SNODGRASS C	25	KRUEGER H	9
BRUNINI A	16	ROIG F	29	DUMAS C	24	PEREZ-DE-TEJADA H	9
DASSO S	16	WINTER OC	29	MANFROID J	23	REYES-RUIZ M	8
DEMOULIN P	16	MICHTCHENKO TA	25	BOEHNHARDT H	19	GONZALEZ-ESPARZA JA	7
BERTUCCI C	11	CARVANO JM	24	CARRY B	18	LARA A	7
MICHTCHENKO TA	11	FERRAZ-MELLO S	23	HAN C	18	OMIDI N	6
DI SISTO RP	10	ALJBAAE S	20	UDRY S	18	AGUILAR-RODRIGUEZ E	5
FERRAZ-MELLO S	10	MOTHE-DINIZ T	18	VERNAZZA P	18	KAJDIC P	5
DE ELIA GC	9	BEAUGE C	15	GOULD A	16	LOOSE A	5
MANDRINI CH	9	LICANDRO J	15	PIETRZYNSKI G	16	RUSSELL CT	5
GIUPPONE CA	8	PRADO AFBA	15	UDALSKI A	16	SEIDENSTICKER KJ	5
DUFFARD R	7	DE LEON J	12	BAYLISS D	15	ALBIN T	4
CANADA-ASSAN-DRI M	6	VOKROUHLICKY D	12	COLAS F	15	ARNOLD W	4
GULISANO AM	6	BARUCCI MA	11	HANUS J	15	CORONA-ROMERO P	4
JANCHES D	6	DUFFARD R	11	LEE CU	15	FISCHER HH	4
MELITA MD	6	PINILLA-ALONSO N	10	MARSSET M	15	ACEVES H	3
MORALES N	6	YOKOYAMA T	10	OPITOM C	15	ESQUIVEL A	3
ORTIZ JL	6	ALVAREZ-CANDAL A	9	RAUER H	15	HIRN A	3

Table 17. Knowledge structures in Biblioshiny for planetary physics.

Knowledge Structures	**Element**	**Result**
Conceptual	Thematic map	Mexico has topics with a high degree of relevance and development (motor themes), while Brazil and Chile have them to a lesser extent. Argentina is behind in this field.
	Co-ocurrence network	Mexico does not present the thematic variety found in Argentina, Brazil, and Chile. These countries have a greater thematic variety.
	Thematic evolution	Brazil and Chile show a greater thematic evolution than Argentina and Mexico.
Intellectual	Co-citations network	Brazil has more integrated cluster, the rest of the countries under study, show isolated clusters that rarely cite each other.
	Historiography	Brazil and Chile show thematic trajectories that are continuous throughout the analysis period, while Mexico and Argentina show no development even though they present a large number of them.
Social	Collaboration network	Brazil has more integrated cluster, while the rest of the countries only show isolated clusters.
	Collaboration map	In general, the four countries have a huge collaboration with USA (Figure 7). In particular, Chile collaborates with many countries, unlike the other countries.

Table taken from the Aleidi Nicolás Pablo MhD thesis.

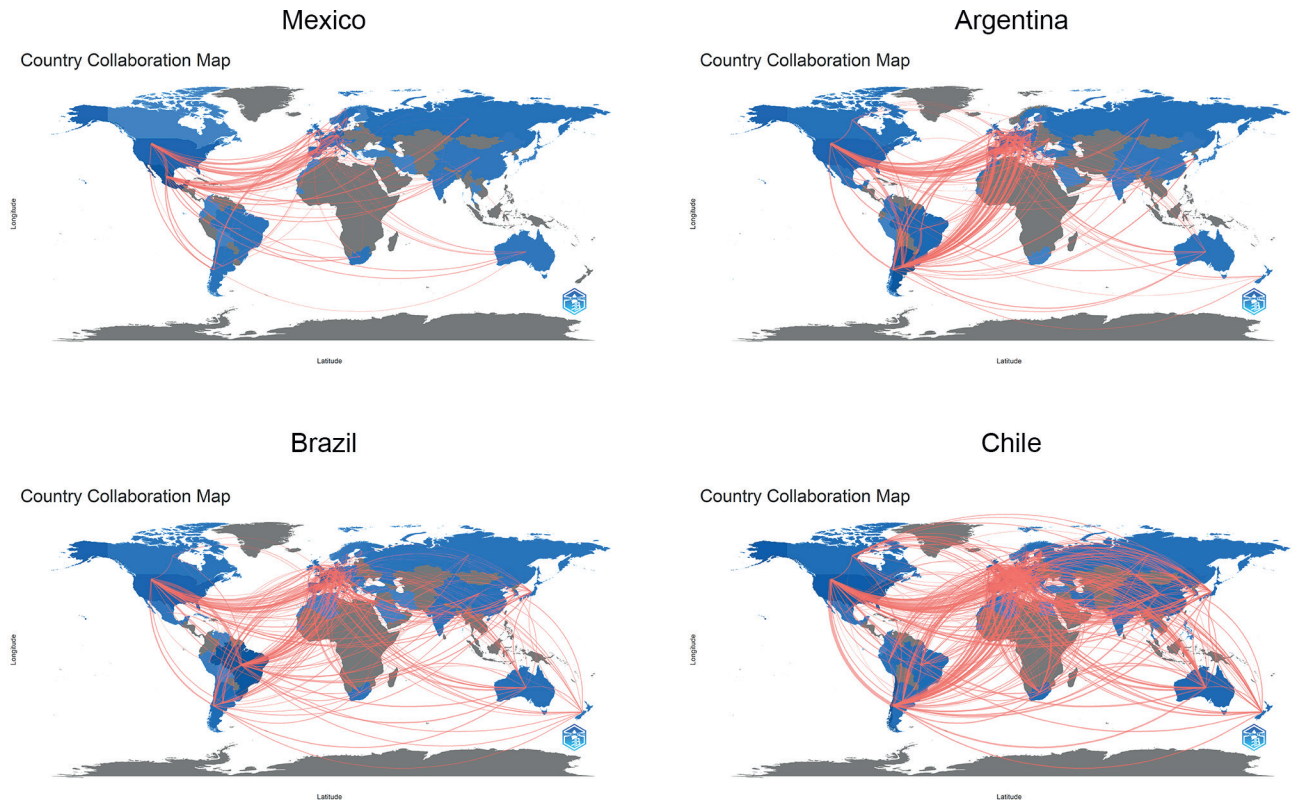

Figure 19. Country collaboration map of Latin American countries in planetary physics. Edges are proportional to number of co-authorships.

have several national affiliations. Results also show that Latin American countries analyzed, practically do not collaborate with each other, although, in 1988, several Latin American countries created an international scientific community on the continent to hold the first Latin American Conference on Space Geophysics (COLAGE – acronym in Spanish). Two of the conference's objectives were to present to the scientific community the topics and work carried out by the attending countries, as well as to create international working groups to solve frontier problems associated with the Solar System. To achieve these objectives, among others, COLAGE is organized every three years in one of the Latin American countries that are part of the Latin American Association of Space Geophysics (ALAGE - acronym in Spanish) and is attended by students and researchers, who work in several areas of space sciences.

The fact that Latin American countries do not collaborate scientifically with each other, according with this work, implies that COLAGE has not yielded results from the perspective of large-scale international collaboration, although there are published papers by small international collaboration groups that have not created significant networks.

Presently, there are efforts to improve the integration of the scientific community dedicated to space issues in Latin America, such as the creation of the Latin American and Caribbean Space Agency (ALCE - acronym in Spanish) on September 18, 2021. However, to achieve this goal it is important to start by filling the gaps in collaboration and productivity found in this work. This will require multidisciplinary work to generate public policies to try to eradicate these problems and the contributions of this research could be the first step to put into context, the current situation of space sciences research in Latin America.

5. Conclusions

This is the first article to present a bibliometric study of Space Sciences in Latin America to identify the most productive countries in the analyzed research areas and to understand the strengths and weaknesses of each country. The study shows that, despite the projects carried out to date to create international collaboration networks and working groups among Latin American countries, favorable results have not yet been obtained according to the bibliometric studies of this work as all the research areas involved generally represent slow or very slow development, short periods of productivity, or periods where development is practically non-existent.

The number of publications has decreased in some areas, such as solar-terrestrial relationships, or is low, as in magnetospheric

physics. However, each country stands out in some of the research areas for the following reasons:

a) Argentina and Mexico, in the area of cosmic rays physics, because they are the countries where this area has been primarily developed and they have infrastructure that can be used to increase their productivity in this field. This fact represents an opportunity to create collaboration networks;
b) Chile, in the areas of solar physics, solar-terrestrial relationships, and planetary physics due to the authorship, co-authorship, productivity, and large international collaboration networks and;
c) Brazil in the areas of solar physics and magnetospheric physics due to the number of authors and productivity´s index.

The four Latin American countries have national affiliations involved in one or more of the five space sciences research areas, such as the University of Buenos Aires in Argentina, the National Institut for Space Research (INPE) in Brazil, the Catholic University in Chile, and the UNAM in Mexico. This study also quantitatively demonstrates that collaboration among Latin American countries is minimal, all four countries collaborate with foreign institutions, as is the case of American institutions and, the dependence on the United States is very high, raising important questions about the need to strengthen intra-regional cooperation.

Finally, the results obtained in this study provide an overview of the current state of space sciences in Brazil, Chile, Argentina, and Mexico, and represent an excellent opportunity for all Latin American countries to create new working groups in the field of space sciences even in other areas such as astrobiology.

Strengthening international scientific collaboration through projects, academic exchange programs, and/or the creation of consortia could generate, in the medium and long term, networks and working groups of scientific relevance in the field of space sciences in Latin America.

6. Declarations

This research was done with the own resources of the corresponding author.

The authors declare that they do not have any conflict of interest.

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