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Involvement of women in the scientific outputs of the National Institute for Space Research (INPE)

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Abstract

Introduction. In research centres, the evaluation of scientific production is of great importance, since various aspects of this production can be analysed, such as co-authorship networks, participation in research projects and in academic juries, to name a few. The aim of this study is to analyse the participation of women researchers in the scientific output of a Brazilian research institution, the National Institute for Space Research (INPE).

Method. A quantitative analysis, complemented by the social network analysis approach, was applied from the perspective of network centrality.

Analysis. The study found that, although the number of women researchers is lower than that of men researchers, they individually have an annual publication rate very close to that of men researchers, as well as participation in numerous research projects and academic juries, contrary to initial expectations and the evidence presented in the theoretical study.

Conclusion. It is hoped that the results of this study will add to the existing knowledge on the contribution of women in the field of space, as well as allowing reflection on the issue of women's participation in science, and encourage actions and policies to stimulate the training of women researchers.

Introduction

Information and knowledge play a strategic role in the midst of growing global economic changes, so that their mapping, when linked to the analysis of collaborative relationships in their production, becomes highly relevant for the competitiveness of organisations. Power no longer resides exclusively in states, institutions or big corporations, but in the networks that structure society (Serrat, 2017, p.39). Scientific collaboration, according to Hajibabaei et al. (2023), 'is driven, in almost all fields, mainly by the need of sharing knowledge, experience and common resources' (p. 1219). Velez-Estevez et al. (2022) state that 'the need for international collaboration has become a common pattern in science, since publications originating from international collaborations tend to achieve greater scientific impact' (p. 7517). In this regard, research centres should be constantly monitored in order to evaluate the scientific production and collaboration of their researchers, as well as their degree of openness in relation to other national and international research centres (Di Bella et al, 2021; Shin et al., 2022).

Our research emerges from the findings of these studies and analyses the participation of women in the scientific collaboration network of a Brazilian research institution in the space field, Instituto Nacional de Pesquisas Espaciais (INPE), the National Institute for Space Research. This institute is headquartered in the city of São José dos Campos, state of São Paulo, and has ten units in other regions, giving it national coverage. Its mission is to produce science and technology, operate systems, train people, and offer differentiated products and services and innovative solutions in the areas of outer space and the Earth system, for the advancement and dissemination of knowledge and sustainable development, for the benefit of Brazil and the world (Instituto Nacional de Pesquisas Espaciais, 2022). It is recognized as a national and international reference centre in the areas of space and atmospheric sciences, covering aspects such as Earth observation through satellite images for environmental monitoring; the study of global climate change; and the identification of impacts on the country. It also plays an important role in providing subsidies for the development of public policies to tackle these challenges, at both national and international levels.

Our research uses the approach of social network analysis, which has its origins in three theoretical fields: sociology, anthropology, and psychology, to identify patterns in groups of people connected by different types of relationships. With this approach, we intend to answer two questions: Is there a disproportion in terms of intellectual production between men and women in this institution? And, Are men and women collaborative with each other and with the outside world in the same way?

Evaluating the performance of institutions through quantitative analysis, using production indicators, combined with a qualitative, more individual analysis of the researchers who work there, can bring advantages and directly affect the management, innovation, financing, and social impact of the research carried out.

This article is divided into six sections. Following the introduction, the second section examines the literature on scientific collaboration and gender inequalities in various scientific fields. The third section discusses social network analysis, an approach used to analyse the scientific production of the institute's researchers, with its metrics of analysis and network development. The fourth section presents the methodological procedures applied in the development of this work. The fifth section presents the results analysis, and the sixth section provides concluding remarks on the research's overall contributions.

Literature review

Due to the increasing importance attributed to collaboration in research, several studies have proposed to investigate the collaborative behaviour of scientists and the existence of patterns of collaboration among them. These include: Di Bella et al. (2021) who analysed the degree of openness of researchers at the Italian Institute of Technology in relation to other national and international research centres; Azimi and Mohammadi (2024), who analysed the scientific cooperation network of ontology researchers using social network indicators and the correlation between centrality indicators and the productivity and efficiency of researchers in this area; and Arroyo Moliner et al. (2017) who analysed the dynamics of research in talent management, presenting a clear picture of their collaboration networks, which was constructed through social network analysis.

On another front, Hajibabaei et al. (2023) examined the collaborative behaviour of scientists in search of the presence of gender-specific patterns in academic relationships. For them, understanding gender aspects in scientific collaboration is of paramount importance since their evidence demonstrates the diffusion of gender inequality in academic activities.

In addition, other studies addressing the issue of gender inequality in academic activities were found (Bakshi-Hamm & Hamm, 2023; Holman et al., 2018; Huang et al., 2020; Larivière et al., 2013), but no studies were found that analysed women's participation in space research. Considering that investigations in space research are often interdisciplinary and multidisciplinary, some studies on this subject were found in areas such as remote sensing, computer science, astronomy, astrophysics, physics, climatology, and engineering.

In remote sensing, Joyce et al. (2022) analysed the editorial board of scientific journals in the field and found that eight of the top ten journals (by Impact Factor) have editorial boards comprised of more than 80% men. In addition, 84% of the journals had less than 20% of women on their boards. The findings reinforce the findings of previous research that there are few women on the editorial boards of scientific journals (p. 2).

Pico et al. (2020) analysed the participation of women in geosciences as first authors in scientific papers and found that their participation drops substantially with each level of career progress, with a greater discrepancy in the highest positions. They presented a factor that potentially obfuscates any analysis of women's representation in science. It is a fact that women are prone to use only the first letter of their first name to mask their gender, as a preventive defence against implicit bias, which has been proven in studies that show that the gender of a name influences competency assessments.

Yuan et al. (2020) found that the field of artificial intelligence (AI) is led by a small group of men scientists, who tend to form close-knit groups. This led the authors to examine the characteristics of influential researchers in this area by analysing gender relations in their collaborative networks. Similarly, Felizardo et al. (2021) carried out a systematic mapping of the participation of Latin American women in the field of software engineering, concluding that their contribution has increased at a global level over the years, but is still concentrated in European countries (p. 10).

In the field of computer science, Jadidi et al. (2018) analysed the collaborative behaviour of scientists, using the social network analysis approach, and found that 'women tend to have smaller and strongly grouped networks and have fewer intermediary functions compared to their male colleagues' (p. 19).

Danesh et al. (2023) presented a study, under the social network analysis approach, of interconnected phenomena on women's participation in editorial boards of astronomy and astrophysics journals. It has been identified that the number of men on these boards is about five times higher than that of women. Additionally, Dabas e Kumar (2018) analysed the research production of women scientists in selected Indian research institutes in physics and astronomy from 2011 to 2015 and observed that the presence of women scientists (12.35%) is lower compared to men scientists (87.65%), where, out of 583 researchers, only seventy-three are women (para. 6).

In the field of climatology, Galbiati and Campos (2021) evaluated the participation of women in the construction of Brazilian climate policy. The report that presented their findings identified 'the predominance of men in the institutional spaces of Brazilian climate governance, with the exception of the Adaptation Working Group, linked to the elaboration of the National Plan for Adaptation to Climate Change' (para. 45). The authors also found a prevalence of men among the members who have decision-making power in the meeting of the collegiate bodies.

Lastly, in engineering, Kemechian et al. (2023) presented a study seeking to understand the main challenges faced by women over time in their careers in Brazil and abroad, focusing on Sustainable Development Goals (SDGs) 5 (gender equality) and 8 (decent work and economic growth) of the UN 2030 agenda. They noted that aptitude does not prevent women from increasing their participation in science, technology, engineering and mathematics (STEM) careers, since this does not differ between men and women (para. 3). They further noted that even when women have the same qualifications as men, pressure and working conditions are additional barriers to advancement in these careers (para. 3). Additionally, strategies have been implemented to increase the number of women seeking to establish themselves in these careers, yet the level of female underrepresentation in these fields has remained stable for decades (para. 5).

This work is justified by the statement of Cândido et al., (2021, p. 6) that scientific articles dealing with gender inequalities in Brazil are rare and mainly descriptive, offering few explanations of these phenomena. In addition, institutions generally present a thematic diversity and structural complexity that makes identifying their academic profiles and standards a challenging task. This is the scenario found in the analysed institution, where, during the literature review, it was found that there was a lack of studies that addressed the mapping and representation of these profiles, highlighting a significant gap and a promising research opportunity.

Thus, based on the assumption that the scientific production of a given institution would be represented by the set of scientific production generated within its scope (Braun, 1999), the study of scientific production, with an emphasis on the analysis of scientific domains and relationships, becomes relevant as it can allow each institution to learn more about its own scientific potential, relying on objective and reliable information to support decision-making, planning and evaluation of its activities.

Social network analysis

Social networks are a finite set of actors (ranging from people to political entities)) and 'the ties and relationships that exist between them' (Wasserman & Faust, 1994, pp. 9, 20), where the presence of relationships is a critical and determining characteristic of the network, since the focus is not on the individuals themselves, but rather a network structure, defined as the set of individuals and their connections. Focusing on relationships and their patterns requires analytical methods and concepts that differ from traditional statistical methods of data analysis.

Another definition is that 'Social networks are nodes of individuals, groups, organizations and related systems that connect in one or more type of interdependencies' (Serrat, 2017, p. 39). Thus, despite being potentially complex structures, analysing them allows us to detect various types of connections between people inside and outside their institutions. The network analyst attempts to model these relationships to describe the structure of a given group. Thus, this *modelling* takes place through the analysis of the co-occurrence of important terms, which reveals patterns and semantic relationships in textual datasets, whether they are keywords, concepts, or other elements, to describe the structure of a specific group or context. According to Robredo and Cunha (1998) 'by analysing the co-occurrences between pairs of words, it is possible to establish statistical indices that represent the "strength" of association between these pairs and, based on the values found, create various types of graphic representations' (p. 11). For Hansenet al., (2011), 'social network analysis is the most comprehensive application of network science to the study of human relationships and connections where technologies change the fabric of the material world, which in turn changes the social world' (p. 179).

Social network analysis is considered a comprehensive tool for studying human relationships and their interconnections, going beyond the simple observation of direct connections, exploring more complex and dynamic patterns in social networks. A field where it is widely used is *research on research*, which involves critical assessments of policies and funding arrangements designed to support the publication of scientific-technical research (Anderson & Evered, 1986; Supplee et al., 2023; Thomas et al., 2020). This reflects a growing interest in understanding how funding and policy decisions impact the production and dissemination of scientific knowledge. According to Thomas et al. (2020), this growing interest goes hand in hand with the change in funding modalities for universities and public research organizations, with an increase in competitive funding of project grants and greater selectivity applied to institutional research funding streams (p. 275). In this context, through social network analysis, influence measures can be used to evaluate research, helping to make better strategic decisions, improving processes ranging from contracting funding to the evaluation of organizations. Thus, with this social structure, the exchange of data and information between members or agents, or even organizations, can be studied and analysed at different levels of detail, but, according to Recuero (2017), what matters in a network analysis study 'is that the object of the work has a mappable structure and that this mapping is useful for understanding the phenomenon that the researcher aims to investigate' (p. 16). Table 1 presents key concepts for a better understanding of social network analysis.

Concepts	Meanings
Nodes or actors	The social entities that share relationships in the network
Links or relationships	The social bonds that connect the nodes/actors
Dyad/triad	Consists of a pair/triple of actors and the possibilities of relationship that arise between them.
Group	Finite set of individuals on which network measurements are made
Density	Number of connections or links between nodes
Diameter	The length of the largest geodesic distance between any pair of nodes

Table 1. Key concepts of social network analysis (Wassermann & Faust, 1994)

Because network measurements produce data that is both social and behavioural, a set of methods has been developed for their analysis. Social network data requires measurements of the links between nodes/actors; attributes of the actors can also be collected for analysis. Table 2 shows some of the measures of analysis (indicators).

Indicators	Meanings
Centrality	When an individual is in a central position in the network.
Degree centrality	How many ties each actor has.
Closeness centrality	Measure of distance (or closeness) between actors without the need of many intermediates.
Betweenness centrality	Intermediation between nonadjacent actors.
Clustering coefficient	Perspective in which two actors connected to specific actors are, also, connected between them.

Table 2. Indicators of social network analysis (Wasserman & Faust, 1994)

A network can be analysed under three aspects: network, where the network as a whole is analysed; individually, where each actor is analysed; and group, where subgroup formations are analysed. In this work, the network aspect will be adopted to analyse interactions between researchers in the context of the analysed institution, because the network scope focuses on the analysis of structure and relationships, considering the network as a whole with its global characteristics such as density, centrality of actors, patterns of connections, and clusters of researchers.

Scientific social networks

Scientific social networks are specific types of networks that represent social interactions arising from the academic environment, where two researchers are considered connected when they are co-authors of at least one scientific paper. According to Martins (2014), this network dynamics considers that authors are entities that evolve over time, as well as their properties and attributes (p.101).

The analysis of this type of network can allow the identification of research communities; researchers who have significant influence; understanding the social evolution of researchers over time; and suggest new relationships to improve research or improve the flow of knowledge in the network, among other things.

According to Bergsma, Mandryk, and McCalla (2014), influence is ‘the ability of a researcher to influence another researcher's opinions, ideas, experimental approaches, or choice of research topics’ (p. 1). They claim that knowing about influential individuals helps to understand how their behaviour interferes in a network. Influence measures can be used to evaluate research, helping to make better strategic decisions, improving processes ranging from contracting funding to evaluating organizations through collaboration.

Sonnenwald (2007, p. 645) defines collaboration as ‘interaction taking place within a social context among two or more researchers that facilitates the sharing of meaning and the completion of tasks with respect to a mutually shared, superordinate goal’, such as co-authorship. Sonnnenwald points out that ‘scientific collaboration is often motivated by the need for access to expensive instruments, unique scientific data, scarce natural resources, social resources, and large amounts of scientific funding’ (p. 654); this is corroborated by Bouabid and Achachi (2022).

Co-authorship networks

Science has proven to be an increasingly global activity (Adams et al., 2014) and due to this globalization of the scientific job market, ‘many countries are implementing policies that promote scientific collaboration and mobility as a way of internationalizing their scientific system’ (Chinchilla-Rodríguez et al., 2018, p.1). It has been claimed that international collaboration promotes the production of high-quality knowledge (Velez-Estevez et al., 2022) and is necessary to solve complex scientific problems (Sonnenwald, 2007, p. 643).

Collaborative partnerships have been shown to be a product of self-organized networks, in which co-authorship is determined through preferential attachment to high-impact and highly visible authors (Wagner & Leydesdorff, 2005); they also bring mutual benefit to collaborators (Chinchilla-Rodríguez et al., 2018, p. 2).

Co-authorship is one of the most important relationships in scientific social networks, as researchers are involved in studies and publications on the same topic and are therefore considered to be more directly related. Most studies on scientific social networks consider the relationship of co-authorship in the construction of the social network.

For Kumar (2015), co-authorship is a product of scientific cooperation and co-authorship networks have been studied in several ways. Ozel (2012a, b) noticed that the cognitive demand of publishing in indexed journals gave way to cohesive collaborative teams, resulting in the collaborative production and transfer of knowledge; Alcaide et al. (2009) used co-authorship network analysis to examine women's participation in Spanish sociological journals. According to Damar et al., (2022), scientific collaborations, national and international, improve relations between institutions by providing appropriate environments for the creation of values that increase scientific and industrial benefits by coming together from different perspectives, including financing by funding agencies. For Chen et al. (2019), revealing the big picture of collaborations requires scientific research to make these collaborations visible, increasing their impact; and bibliometrics and scientometrics are the indicated approaches for this purpose.

In this sense, this work employs scientometrics from the perspective of social network analysis to map the scientific relationships between researchers in a research institute using co-authorship network analysis.

Methodological procedures

Methodologically, this work follows the model proposed by Saunders, Thornhill and Lewis (2016) called 'The research onion', which presents itself as a case study, interpretivist, with an inductive approach, a qualitative-quantitative method, of a descriptive nature that is close to explanatory. To this end, it uses co-authorship links as a measure of scientific collaboration to identify patterns of collaboration, from a gender perspective, among researchers at the National Institute for Space Research.

Data on the scientific activities of the institution's researchers and research groups were collected through automated data collection on the Lattes/CNPq platform (Brazil), using a list of the CPF (Individual Taxpayer Registry at the Federal Revenue Service of Brazil) numbers of their researchers. From the data collected, information about the curricula was extracted, including participation in projects and juries of master's and PhDs. The listing of the CPF numbers of the institution's researchers was also important for identifying the authors' genders, which are never directly accessible in the publication databases.

In April 2023, the Scopus and Web of Science (WoS) databases were searched for articles published by the Institute's researchers over the five years immediately preceding the start of the research (2018 to 2022). A total of 4,093 articles were found, of which 2,464 were in Scopus and 1,629 were in WoS. Of these articles, 1,372 were removed for being duplicates and another 242 were removed for presenting inconsistencies in the metadata, such as blank fields in the title or field of knowledge, which resulted in 2,479 publication records. The search for publications was carried out in these databases and not in the Lattes platform, as many researchers do not update the data on this platform frequently.

The data obtained were then processed (unified and normalised) using the Bibliometrix library in the R Studio software. Finally, the processed data set was used to analyse the Institute's collaborative networks, which allowed the participation of men and women researchers in these networks to be presented through graphical visualisations created using the VOSviewer software.

Results analysis

This section presents the analysis of the Institute's scientific collaboration networks, based on the number of publications indexed in the Scopus and Web of Science databases in the period 2018-2022.

Co-authorship networks

The analysed dataset contains the metadata of 2,479 publications, authored by 227 researchers of the institute, of which 49 (21%) are women and 178 (79%) are men (Figure 1).

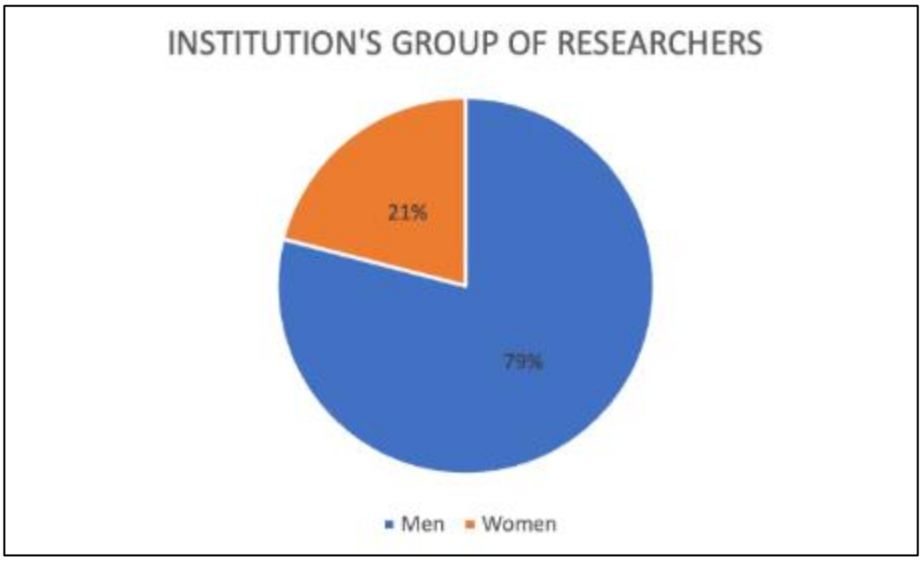

Figure 1. Composition of the Institute's researchers by gender

Figure 1 shows the significant disproportion in the number of researchers by gender, since the presence of women researchers in the Institute is considerably smaller than that of men researchers. However, when analysing the average annual productivity of this group of researchers by participation (authorship or co-authorship) in the Institute's publications for the period researched, we can already find an answer to the first question initially asked in this work: is there a disproportion, in terms of intellectual production, between men and women researchers in this institution?

In Figure 2, despite the large difference in the number of men and women in the Institute's researchers, the annual average of publications of both is very close and behaves in the same way throughout the period studied.

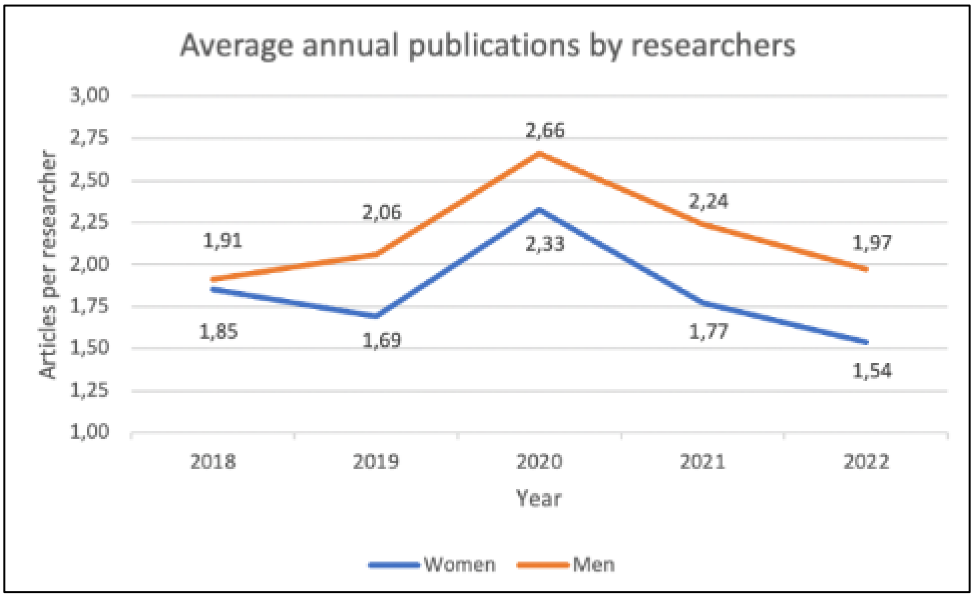

Figure 2. Publication rates by men and women researchers

Considering the social network analysis approach, the network aspect was adopted to analyse the interactions between the researchers, in which the network scope focuses on the analysis of structure and relationships. For the bibliometric analysis of the interaction between authors, centrality measures are used, where the higher the degree of connection of a researcher to the others, the more central the researcher is.

Initially, the researchers' internal collaboration networks were analysed by gender. Figure 3 shows the formation of fourteen clusters in the men's network, which, as defined by Newman (2012), are dense sub-networks within a larger network. This raises the question: Are men collaborative with each other?

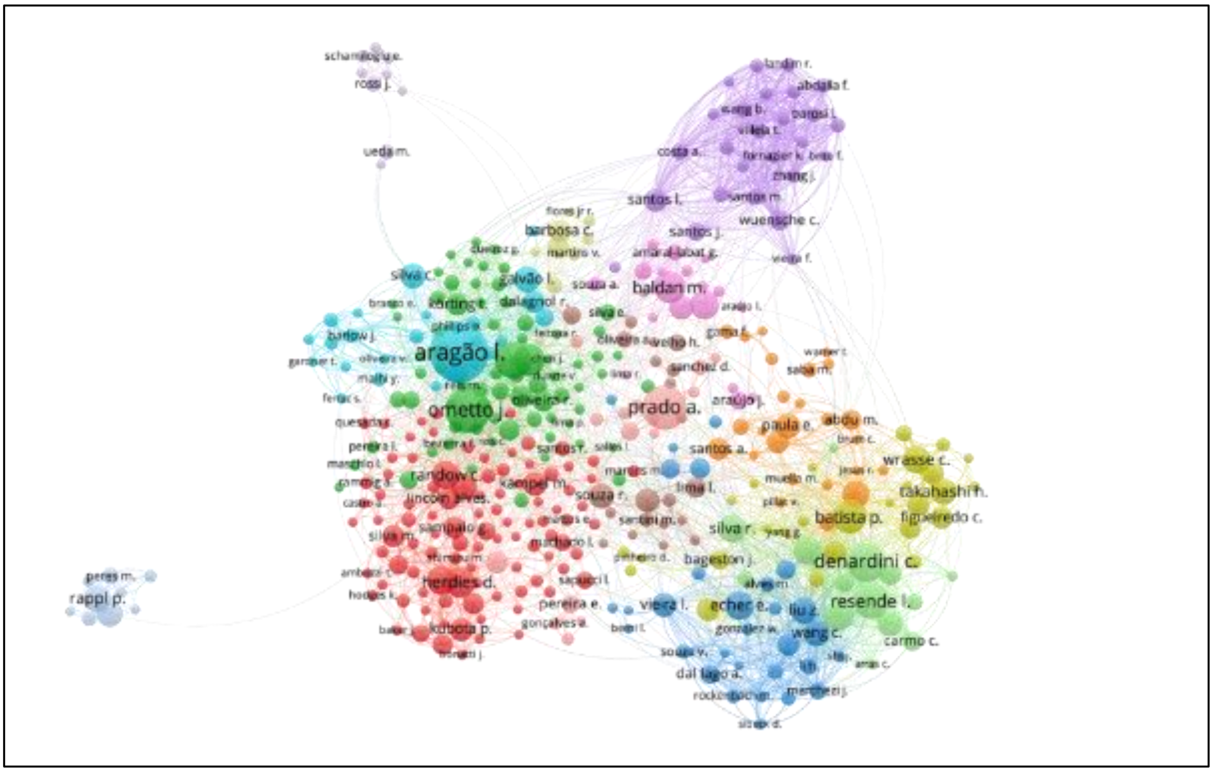

Figure 3. Men collaboration network

Table 3 represents the men network of collaboration between the authors, where each colour is the same as that represented in the network in Figure 3.

Cluster Colour	Actor	Links	*Degree Centrality*	*Closeness Centrality*	*Betweenness Centrality*
1	Randow C.	49	yes	yes	yes
2	Ometto J. and Shimabukuro Y.	57			
3	Vieira L.	38			yes
4	Batista P.	39			yes
5	Santos L.	52		yes	
6	Aragão L.	101		yes	
7	Paula E.	35		yes	
8	Souza R.	32			yes
9	Baldan M.	20			
10	Prado A.	16	yes	yes	
11	Denardini C.	62	yes		yes
12	Rappl P. e Abramof E	9			
13	Barbosa C.	15			
14	Rossi J.	7			yes

Table 3. Description of men collaboration network

In this network it is possible to observe that the most representative actors are: Aragão L. (cluster 6, turquoise blue), Denardini C. (cluster 11, light green), Ometto J. and Shimabukuro Y. (cluster 2, green), Santos L. (cluster 5, purple) and Randow C. (cluster 1, red). Aragão L., from the Remote Sensing area, is the most representative of the entire network. He has centrality with 101 links. He presents proximity centrality, that is, short connection paths with actors inside and outside his cluster, in addition to a large number of publications (eighty-three). Denardini C., from the area of Space and Atmospheric Sciences, has sixty-two links, with degree and betweenness centrality, since it occupies an important bridge position with several clusters.

In cluster 2 we have two authors who can be considered central, Ometto J. from the Space and Atmospheric Sciences field and Shimabukuro Y., from the Remote Sensing field. Both have the same number of direct links (fifty-seven), but Shimabukuro Y. has a higher number of indirect links 158, and Ometto J. has a higher number of publications (fifty-five). In short, the two authors play an important role in this cluster. Santos L. (cluster 5, purple, upper right corner of the network) from the Aerospace Engineering area, has fifty-two direct links. Despite his centrality in the network and a high degree of proximity, most of his links are with authors external to the Institute. Randow C., the fifty most representative actor in the network, from the area of Earth System Science, leads his cluster with forty-nine links. In addition to centrality, he also has degree, proximity and betweenness centrality. Prado A. (cluster 10, pink), from the Aerospace Engineering area, has the centrality of his cluster, with sixteen links and fifty-four publications, meaning that the author always publishes with the same authors. The author presents centrality of degree and proximity. The other actors in the other clusters follow more or less the same pattern of relationships.

Answering the question about men collaboration, it is possible to observe that men tend to collaborate intensely, but with a large part of the colleagues in their cluster, some working alone, and are collaborative with authors external to the institution.

Next, Figure 4 presents the collaboration network between female researchers, made up of 377 authors, among which forty-nine are working researchers, where it is possible to verify a total of fifteen clusters, and present the same question asked in the previous Figure: 'are women collaborative with each other?'.

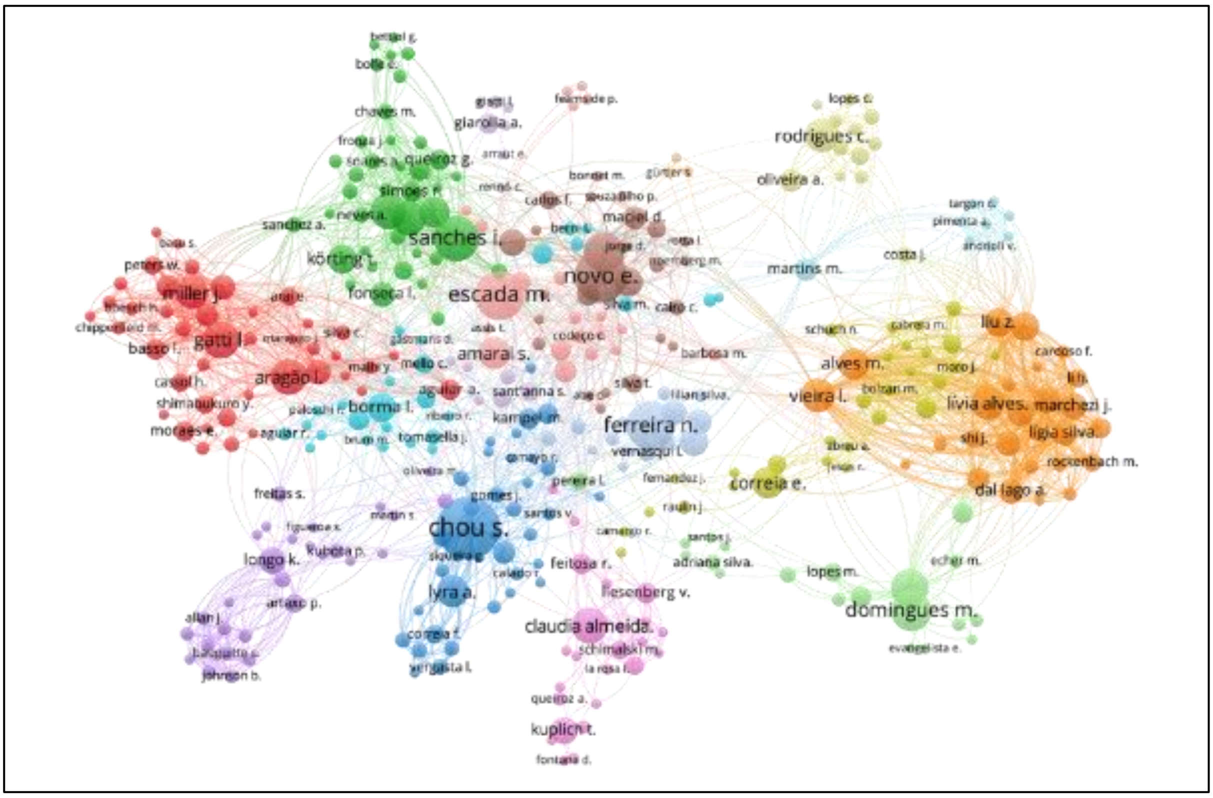

Figure 4. Women collaboration network

Table 4 represents the women network of collaboration between the authors, where each colour is the same as that represented in the network in Figure 4.

Cluster Colour	Actor	Links	*Degree Centrality*	*Closeness Centrality*	*Betweenness Centrality*
1	Gatti L.	42	yes	yes	
2	Sanches I.	45	yes	yes	yes
3	Chou S.	44	yes		yes
4	Correia E.	19		yes	
5	Longo K.	25			
6	Borma L.	25	yes	yes	
7	Alves L.	44		yes	
8	Novo E.	37	yes	yes	
9	Almeida Cláudia	20			
10	Escada M.	42	yes	yes	
11	Domingues M.	15			yes
12	Ferreira N.	22			
13	Rodrigues C.	15		yes	
14	Giarolla A.	8		yes	
15	Martins M.	35			yes

Table 4. Description of women collaboration network

In this network the most representative actors are Sanches I. (cluster 2, dark green), Chou S. and Alves L. (cluster 3, dark blue and 7, orange), Gatti L. and Escada M. (cluster 1, red and 10, pink). The actor with the greatest representation in terms of direct links, Sanches I., from the Remote Sensing area, has the centrality of his cluster with forty-five direct connections. He presents three levels of centrality: degree centrality, proximity and betweenness. The second and third most representative actors, Chou S., from the Center for Weather Forecasting and Climate Studies, and Alves L., from the area of Space and Atmospheric Sciences, lead their clusters with forty-four direct links each. Alves L. has a greater number of indirect links than Chou S., but Chou S. is the author with the largest number of publications in the period surveyed, that is, she is an important node in the network with a high degree of intermediation centrality, which means interaction between non-adjacent authors and a high clustering coefficient, which means the density of the ego network of a given agent. The fourth and fifth most representative actors are Gatti L., from the Earth System Science area, and Escada M., from the Remote Sensing area, presenting forty-two direct links each. Gatti L., like Escada M., presents high degree centrality and closeness centrality. Gatti L. presents a greater number of indirect links and Escada M. presents links with authors external to the Institute.

Concluding the analysis of the women collaboration network, we can verify that, by answering the aforementioned question, women are collaborative among themselves and with authors external to the institution, just like men researchers.

Next, Figure 5 shows the collaboration network between the institution's researchers. The merger of the two collaboration networks resulted in fourteen clusters, which will be described below, presenting only the central nodes (authors) of each cluster, without connection analysis, which has already been carried out in previous networks (Table 5).

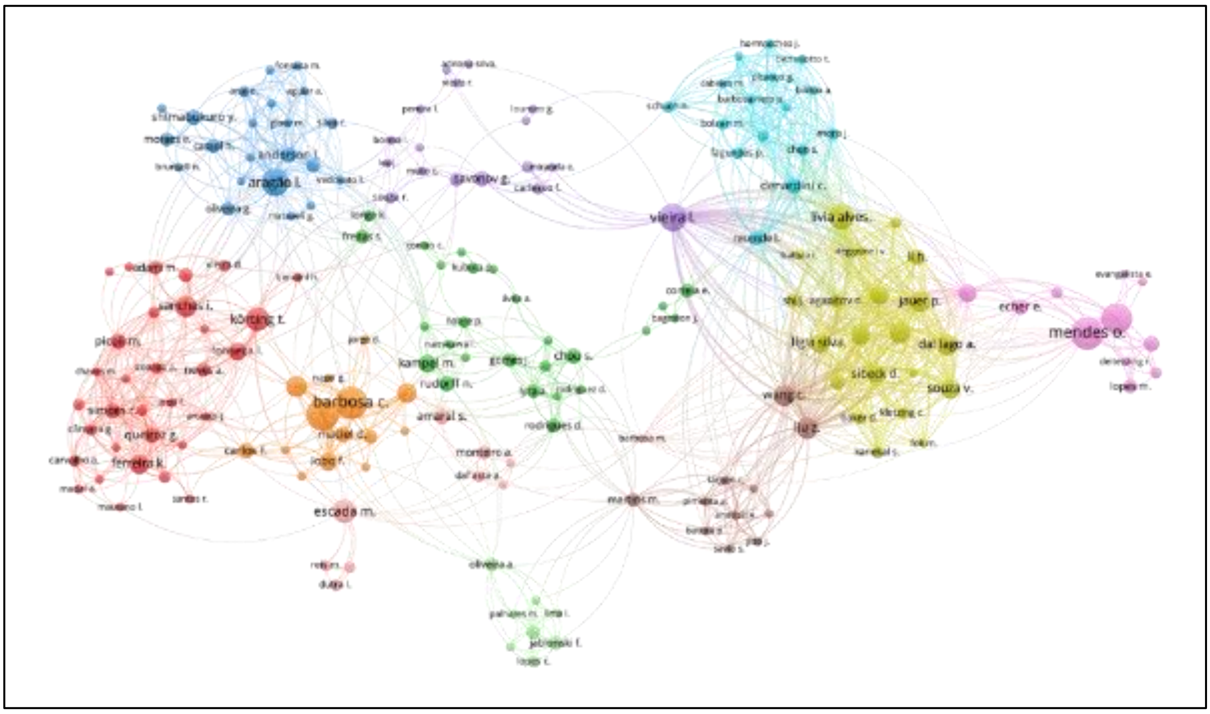

Figure 5. Mixed collaboration network

Table 5 represents the mixed network of collaboration between the authors, where each colour is the same as that represented in the network in Figure 5.

Cluster	Man	Woman	Links
1	Korting T. (Thales)		26
2	Gomes J. (Jorge)		16
3	Aragão L. (Luís)		39
4		Alves L. (Lívia)	43
5	Vieira L. (Luís)		39
6		Resende L. (Laysa)	40
7	Martins V. (Vítor)		19
8		Martins M. (Maria)	25
9	Gonzalez W. (Walter)		33
10		Escada M. (Maria)	16
11	Jablonski F. (Francisco)	Rodrigues C. (Cláudia)	8
12	Rossi J. (José)	Rangel E. (Elizete)	21
13	Ometto J. (Jean)	Giarolla A. (Andreia)	1
14	Velho H. (Haroldo)	Anoci J. (Juliana)	1

Table 5. Description of the mixed collaboration network

By carrying out a comparative analysis between the two collaboration networks, men and women, when observing the number of lines between the nodes, we see that men tend to collaborate more intensely with a large part of the colleagues in their cluster (field or research group), while women tend to collaborate less intensely and with fewer colleagues within their cluster, reinforcing the fact that women represent only 21% of the total number of researchers. In addition, it was possible to identify that men have centrality in six clusters, while women have centrality in four clusters, and in four clusters there was a tie in centrality.

When comparing collaborations between men and women, it is observed that of the 465 articles published where women appear as authors or co-authors, only thirty-seven articles (7.9%) have men from the Institute as authors or co-authors. On the other hand, of the 2,014 articles published where men appear as authors or co-authors, only 108 articles (5.4%) have co-authorships with women from the Institute (Table 6). The remaining co-authorships were with external authors.

Researchers	Publications	Co-authorships (with the opposite gender)	Percentage
Women	465	37	7,9
Men	2.014	108	5,4

Table 6. Collaborations between men and women

This corroborates the study of Jadidi et al. (2018) who found that women tend to have smaller, but at the same time, more grouped networks, with fewer intermediary functions compared to their men counterparts.

Participation in research projects and academic committees

Women's participation in research projects and academic committees provided a comprehensive view of women's research activities at the Institute. As mentioned above, this information was extracted from the Lattes/CNPq platform.

A total of 955 national and international projects in which the Institute's researchers are involved were identified. Among these, 800 are developed by the Institute itself (83.8%) and 155 projects involve another sixty-six institutions (16.2%). The predominance of internal projects indicates a significant focus on internal research and technology development.

Furthermore, forty-four women researchers were identified as involved in 193 projects, while 168 men researchers are involved in 762 research projects (see Table 7). This means that each woman participated, on average, in 4.4 projects, while each man took part, on average, in 4.5 projects.

Gender	Quantity	Projects	Average	Mode
Female	44	193	4.4	1
Men	168	762	4.5	1
Total	**212**	**955**		

Table 7. Participation of men and women in research projects

Regarding the analysis of participation in academic committees, in the search for participation in master's defences, 545 dissertations were identified, of which 355 were defended at the analysed institution (65.13%) and 190 (34.86%) were defended at another fifty institutions.

Once again, it is possible to note the important participation of women in the institution's research: twenty-eight women researchers participated in 166 defences, while ninety-eight men researchers participated in 379 defences. This means women participated in 5.9 committees each on average, while men participated in 3.9 committees each on average. This difference is significant. Women have participated in 138 committees as members, seven as co-advisors, and twenty-one as advisors. Men participated in 307 committees as members, fourteen as co-advisors, and fifty-eight as advisors, as shown in Table 8 below.

Gender	Quantity	Master's defences	Average	Mode
Women	28	166	5,9	1, 4
Men	98	379	3,9	1
Total	**126**	**545**		

Table 8. Men and women in master's defences

Analysing the master's defences, there are two elements that are most repeated in the women group, i.e., two values that have a higher frequency, which configures a bimodal set, Mo = {1, 4}. This means that the same number of researchers participated in one and four master's defences each (researchers Ortiz J., Barreto P., Okamoto S., Dominici T. and Algarve V. participated in one defence each; Correia E., Costa I., Mattiello-Francisco M., Martins M. and Alves M. in four defences each). Table 9 shows the participation of men and women according to the committees' modalities.

Gender	Members	Co-advisors	Advisors	Total
Women	138	7	21	**166**
Men	307	14	58	**379**

Table 9. Participation by modalities in master's defences

Regarding participation in doctoral committees (Table 10), 452 theses were identified, of which 267 were defended at the Institute (59.07%) and 185 (40.92%) were defended at forty-three other institutions. Women's participation was once again significant, with an average of 5.1 committees each, while men had an average participation of 3.3 committees each. In the PhD defences, there are twenty-six women researchers who participated in 133 defences, while the ninety-five men researchers participated in 319 defences. Finally, women participated in 104 committees as members, in eleven as co-advisors, and in eighteen as advisors. Men participated in 264 committees as members, fifteen as co-advisors, and forty as advisors.

Gender	Quantity	PhD juries	Average	Mode
Women	26	133	5.1	1, 3, 4
Men	95	319	3.3	1
Total	**121**	**452**		

Table 10. Men and women in PhD juries

In the set of PhD juries, also in the women group, there are three elements that are most repeated, characterizing a trimodal set, Mo = {1, 3, 4}. Researchers Genaro A., Alves L., Okamoto S. and Dominici T. participated in one doctoral jury; Silva A. (Adriana), Rabello A., An Chen and Oliveira N. participated in three juries; while Mello C., Rodrigues C., Mattiello-Francisco M. and Martins M. participated in four juries (Table 11).

Gender	Members	Co-advisors	Advisors	Total
Women	104	11	18	**133**
Men	264	15	40	**319**

Table 11. Participation by modalities in PhD juries

When analysing gender aspects in scientific production and collaboration, as proposed by Hajibabaei et al. (2023), it was found that women are as productive as men, contrary to the initial expectations and evidence found in studies presented in the literature review (namely, Dabas & Kumar, 2018; Danesh et al., 2023; Johannesen et al., 2022; Joyce et al., 2022; Kemechian et al., 2023; Legg et al., 2023; Pico et al., 2020; Yuan et al., 2020). The study also corroborates the findings of Cândido et al. (2021) and Moschkovich and Almeida (2015), which show that women have to match men in terms of publication rates, while also dealing with domestic and maternity issues, and yet still prove to be very productive. In the case of the analysed Institute, they had higher levels of participation in academic projects and committees.

Thus, having presented the results, which confirm the significant participation of women in research at the Institute, the following section presents the final considerations.

Final considerations

Space research is interdisciplinary and multidisciplinary in nature. Its progress requires researchers to have a wide range of skills, with scientific collaboration playing a key role in sharing knowledge, experience, and resources. Using the social network analysis approach, it was possible to establish that space research within the National Institute for Space Research (INPE) is led by groups of researchers who are predominantly men, with little collaboration between them and women, although the average annual productivity in terms of scientific publications of men and women is similar.

The participation of women researchers in research projects and scientific committees was significant and well above that of men researchers, especially given the large difference in the number of men and women members of the Institute's research group.

Thus, when analysing gender aspects of scientific production and collaboration, the Institute found that, despite being less numerous, women were just as productive as men, contrary to initial expectations and the evidence found in the literature review for this study. This answers our first research question: Is there a difference between men and women, in terms of research?: the study showed that there is no difference. Despite having to publish at the same rate in prestigious journals, achieving the same goals as men, and dealing with domestic and maternity issues, in the case of this Institute's employees they had very similar levels of publication and higher levels of participation in projects and academic committees.

With regard to the second question: Are men and women collaborative with each other and with the outside?, it was evidenced that women collaborate more with each other and less with men, while the opposite is true, men collaborate less with women and more with each other.

Women tend to have smaller, tightly grouped networks with fewer intermediary functions compared to their men counterparts, and some of them are more collaborative with authors outside the Institute (this applies to some men also). However, we emphasize that these data were extracted from scientific databases limited to a five-year period of analysis. Nevertheless, patterns of collaboration between men and women within publication co-authorship networks have been identified based on data collected from the indexed databases.

The analysis performed in this study was conducted in a single institution, a space research centre, because no previous studies were found that evaluated the participation of women in this field. Furthermore, this institution stands out within the Ministry to which it belongs (the Ministry of Science, Technology and Innovation) as having the largest number of researchers and significant scientific production, which makes it relevant for the analysis. For this reason, no comparative analyses with other institutions, either national or international, were carried out.

The next stages of this study will explore all the interconnections and ramifications of the networks that have been created, seeking a greater level of detail in terms of densities, centralities, intermediations, and clusters, in order to answer other questions related to scientific collaboration from a gender perspective in this institution.

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