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Literature Review

Astrotourism research landscape: a bibliometric analysis

Panorama de la investigación en astroturismo: un análisis bibliométrico

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ABSTRACT

Astrotourism, also known as stellar tourism, involves the development of recreational and educational activities related to the cosmos and astronomical phenomena. This type of special interest tourism focuses on nature, culture, and conservation, and stands out for its exceptional economic, social, and cultural benefits. The aim of the study was to analyze the scientific production on astrotourism based on PRISMA guidelines and a review of the Web of Science and Scopus databases (up to December 2022). The applied methodology consisted of bibliometric analysis and mapping of the literature, carried out using the Bibliometrix program, which found a total of 45 articles in 36 journals. The results revealed a growing scientific production, concentrated in few journals, scattered among multiple authors, and limited thematic diversity divided into twelve clusters, which were classified using the Callon algorithm (niche, motor, basic, and emerging/declining themes). It is concluded that astrotourism is a dynamic and consensual topic of study regarding its regional sustainable development contribution and educational capacity on the heritage and aesthetic value of the skies.

Keywords: *Astrotourism, Stargazing tourism, Special Interest Tourism, Bibliometric analysis.*

RESUMEN

El astroturismo, conocido también como turismo estelar, comprende el desarrollo de actividades recreativas y educativas relacionadas con el cosmos y los fenómenos astronómicos. Este tipo de turismo de intereses especiales se enfoca en la naturaleza, la cultura y la conservación, y se destaca por sus beneficios económicos, sociales y culturales excepcionales El estudio planteó por objetivo analizar la producción científica sobre el astroturismo, con base en las indicaciones PRISMA y la revisión de las bases de datos Web of Science y Scopus (hasta diciembre de 2022). La metodología aplicada consistió en un análisis y mapeo bibliométrico de la literatura, mediante el programa Bibliometrix, que halló un total de 45 artículos en 36 revistas. Los resultados revelaron una producción científica creciente, concentrada en pocas revistas, disgregada en varios autores, y una diversidad temática limitada dividida en doce clústeres, que fueron clasificados mediante el algoritmo de Callon (temas de nicho, motores, básicos y emergentes/declive). Se concluye que el turismo astronómico es un tema dinámico de estudio y consensuado respecto de su contribución al desarrollo sostenible regional y su capacidad educativa sobre el valor patrimonial y estético de los cielos.

Palabras clave: Astroturismo, Turismo de las estrellas, Turismo de Intereses Especiales, Análisis bibliométrico.

INTRODUCTION

Astrotourism is a type of special interest tourism (SIT) that focuses on observing and contemplating the night sky, including stars, planets, constellations, and other celestial bodies. It is understood as an emerging type of sustainable tourism based on the observation of dark skies, free of light pollution, and all the experiences offered around it (Araya-Pizarro, 2020; Escario-Sierra et al., 2022). This tourism activity has gained relevance due to the development of new technologies, general interest in outer space, and joint effort of astronomers, academics, ecologist, and associated groups to defend starry skies (Tapada et al., 2021). This has led to an increase in scientific studies related to stargazing tourism.

The multidisciplinary nature of astrotourism makes it a challenging subject for researchers, as it combines elements of astronomy, physics, geology, biology, and ecology, and other fields. By examining scientific production in this area, new related topics can be discovered that can contribute to a greater understanding of the universe.

In this regard, the bibliometric analysis of the literature is a recognized method for exploring and examining large amounts of data, providing an extensive perspective of the study are, evaluating the evolution of a specific field, and discovering new research opportunities (Donthu et al., 2021). This technique allows for determining the evolution of scientific production, the most relevant authors, the most cited journals, the most productive institutions, the geographical distribution of contributions, among other aspects. It is also possible to identify the main topics, challenges, and trends in research that have received attention from the scientific community in general.

In this context, this research aimed to analyze the scientific production on astrotourism (up to December 2022) based on PRISMA guidelines and a review of the most recognized databases worldwide, Web of Science and Scopus (Zhu & Liu, 2020). Its approach, based on clustering the themes derived from the study of global astrotourism, from a quantitative perspective, sets it apart from previous bibliometric analyses, allowing it to complement the existing scarce literature on the topic (Tapada et al., 2021).

The application of bibliometric analysis in astrotourism can offer a broad view of how this tourism activity influences the economy and the preservation of natural and cultural heritage, as well as providing tourism professionals with a better understanding of the interests and needs of tourists, allowing for improved planning and offering of services related to astrotourism. Additionally, identifying gaps or deficiencies in scientific research in astrotourism can motivate new studies to address emerging issues in this field. For all of these reasons, bibliometric analysis can contribute significantly to deepening the challenges, trends, and methods associated with exploring the sky, as well as promoting the development of more research in this area.

This article is organized into three sections, following this introduction. First, the research methodology is described. Second, the findings of the applied bibliometric analysis are synthesized. Third, the results are discussed, and the main conclusions of the research are detailed.

METHODOLOGY

To analyze scientific production related to astrotourism, references and publication citation databases from Web of Science (WoS) and Scopus, two of the most renowned scientific repositories in the world, were reviewed (Zhu & Liu, 2020).

To data collection, words associated with astrotourism such as astronomical tourism, celestial ecotourism, star tourism, dark sky tourism, etc. The results were filtered applying inclusion and exclusion criteria listed in Table 1.

Table 1. Inclusion and exclusion criteria for the search and selection of scientific production

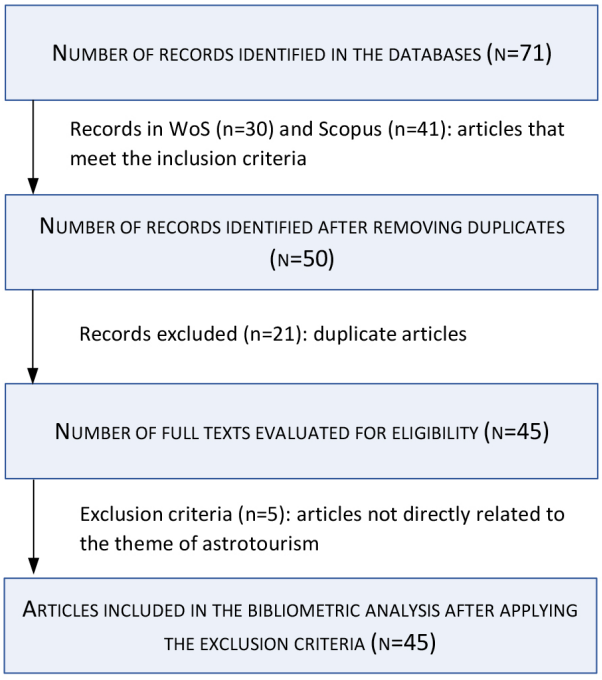
Criteria	Inclusion	Exclusion
Period	Until December 2022	Publications after December 2022
Document type	Scientific article,	Conference papers and publications, Reviews, Books, Book chapters, Notes, Letters, Editorial publications and abstracts
Document status	Final	Article in press
Relevance	Direct handling of astrotourism (key concepts) and related topics	Other unrelated topics

Source: Primary compilation

The scrutiny of the databases, WoS and Scopus, was carried out in March 2023, and the search procedure was represented by the following equations, according to the consulted database. For Scopus, the algorithm was defined by: TITLE-ABS-KEY ("Astronomical ecotourism camps" OR "Astronomical outreach" OR "Astronomical tourism" OR "Astro-tour*" OR "Astrotour*" OR "Aurora borealis tourism" OR "Aurora tourists" OR "Celestial ecotourism" OR "Dark sk* tour*" OR "Northern lights tourism" OR "Tall ship astronomy cruises" OR "star tourism" OR "Stargaz*+tourism") AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")). While for WoS database, it was established as: TS=("Astronomical ecotourism camps" OR "Astronomical outreach" OR "Astronomical tourism" OR "Astro-tour*" OR "Astrotour*" OR "Aurora borealis tourism" OR "Aurora tourists" OR "Celestial ecotourism" OR "Dark sk* tour*" OR "Northern lights tourism" OR "Tall ship astronomy cruises" OR "star tourism" OR "Stargaz*+tourism") AND (DT=(Article)).

The 71 obtained articles were examined following the guidelines of the PRISMA Declaration (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) in their phases of identification, screening, eligibility, and inclusion (Moher et al., 2009), obtaining a final sample of 45 articles, as illustrated in Figure 1.

Figure 1. Diagram based of the PRISMA methodology



The subsequent analysis considered the application of a set of bibliometric methods and network mapping (Cobo et al., 2011b; Muñoz-Leiva et al., 2012). That is, descriptive measures and indexes of the volume, dispersion, distribution, growth of scientific literature, author concentration (Lotka's law), and literature dispersion (Bradford's Law) were calculated. In addition, co-occurrence networks of keywords were designed, and a thematic map of author keywords was constructed. This chart catalogs the study topics based on the strength of internal group associations (density) and the degree of network interaction with other networks (centrality). The result of the categorization is a map composed of four dimensions: motor themes (high density-centrality), basic themes (high centrality and low density), niche themes (low centrality and high density), and emerging or declining themes (low centrality-density) (Callon et al., 1991).

Finally, it is worth noting that bibliometric analysis and network mapping were performed using the Bibliometrix program. This is a package for the statistical programming language R used for quantitative research in scientometrics and bibliometrics. Its functions include statistical analysis, data preprocessing, construction of co-occurrence matrices, co-citation analysis, coupling analysis, co-word analysis, and cluster analysis (Aria & Cuccurullo, 2017).

RESULTS

Sample characterization

A total of 45 documents from 36 journals were retrieved, with an average of 6.5 citations per article. Additionally, 85 automatically generated Keyword Plus and 164 author keywords were identified. Moreover, a total of 126 authors contributed to the field of astrotourism, and 10 of them corresponded to single-author documents. It was also evidenced that each document had an average of 3.1 co-authors, and there was a 13.3% rate of international co-authorship (Table 2).

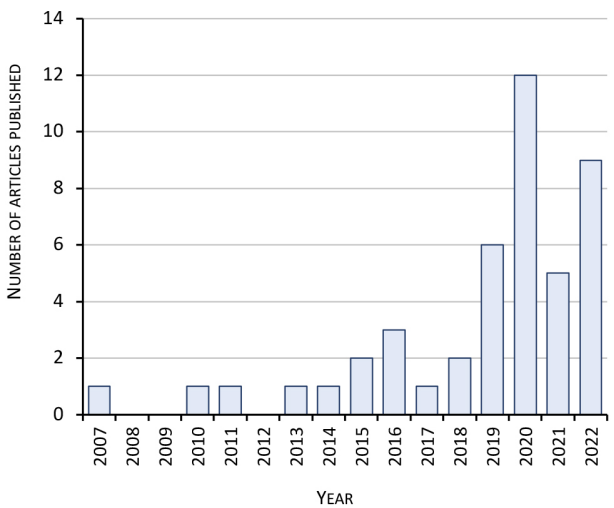
Table 2. Sample characterization

Dimension	Description	Results
Scientific production	Timespan	2007:2022
	Sources (Journals)	36
Documents	Documents	45
	Document Average Age	4.27
	Average citations per doc	6.51
Authors	Keywords Plus (ID)	85
	Author's Keywords (DE)	164
Collaboration	Authors	126
	Authors of single-authored docs	10
	Single-authored docs	10
	Co-Authors per Doc	3.11
	International co-authorships %	13.33

Scientific production

During the analyzed period, a positive trend in scientific production was evidenced, with an average annual growth rate of 15.78%. From the year 2013, the publication of articles has remained active, and the highest record of publications was achieved in 2020, with a total of 12 articles (Figure 2).

Figure 2. Evolution of scientific production



Specifically, the linear regression during the period 2013-2022 revealed an increase of approximatley 1 article per year (β= 0.97, R2= .6). However, it should be noted that the temporal evolution of scientific production fits better with an exponential growth of the literature (β= 0.26, R2= .71) (Table 3).

Table 3. Linear and exponential estimation of the scientific production growth, 2013-2022

Regression	R2	F	Significance	Constant	β
Linear	.599	11.929	.009**	-6.952	0.970
Exponentialq	.711	19.638	.002**	0.146	0.259

Note: y = number of publications; x = periods (1-10), **p<.01

Most relevant authors

A low density in authorship of scientific production on astrotourism was observed, manifested in the reduced number of publications per researcher. The most productive authors published a maximum of 3 articles each. Among them, Carlos Costa, Carlos Peixeira Marques, Carla Susana Marques, Áurea Rodrigues, and Alberto Tapada stood out. It is important to highlight the collaborative work of Costa, Marques C.P., Marques C.S., and Tapada, who always published jointly. Furthermore, the most cited authors were Bente Heimtun and Martin Labuda, with 12 and 11 mentions respectively (Table 4).

The analysis of author concentration using Lotka's Law (Lotka, 1926) confirmed the wide dispersion of scientific production. In particular, it was established that 92.9% of authors have published only one document, 3.2% have published two articles, and only 3.9% have published more than two articles (Figure 3).

Table 4. Ranking of the most productive authors (more than one article)

Ranking	Author	Affiliation	Articles	H-Index	Total citations	Average citations
1	Costa, C.	University of Aveiro	3	1	2	0.7
2	Marques, C.P.	University of Trás-os-Montes and Alto Douro	3	1	2	0.7
3	Marques, C.S.	University of Trás-os-Montes and Alto Douro	3	1	2	0.7
4	Rodrigues, A	University of Évora	3	2	7	2.3
5	Tapada. A	University of Trás-os-Montes and Alto Douro	3	1	2	0.7
6	Heimtun, B.	UiT The Arctic University of Norway	2	1	12	6.0
7	Labuda, M.	Comenius University	2	2	11	5.5
8	Loureiro, S.	ISCTE – University Institute of Lisbon	2	2	5	2.5
9	Pereira, R.	University of Algarve	2	2	4	2.0

Figure 3. Lotka's Law

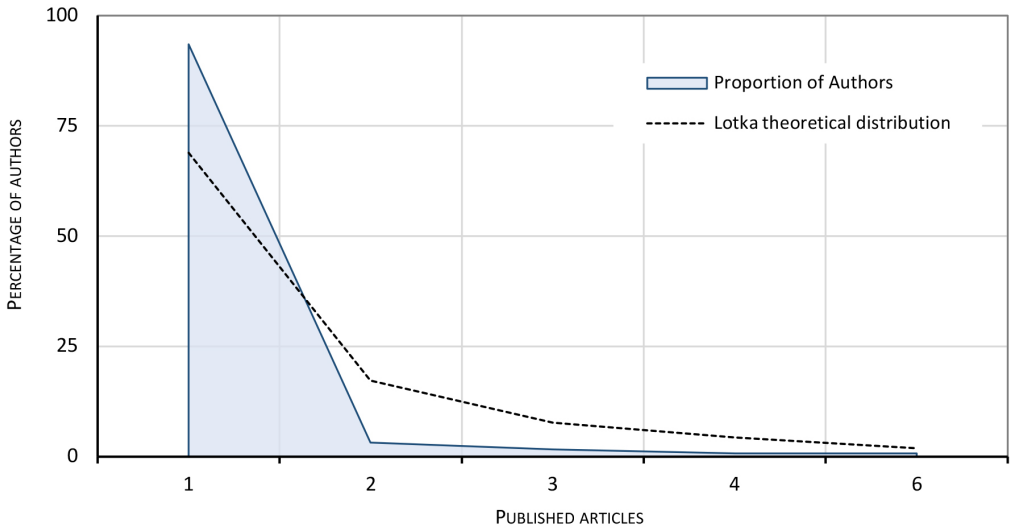
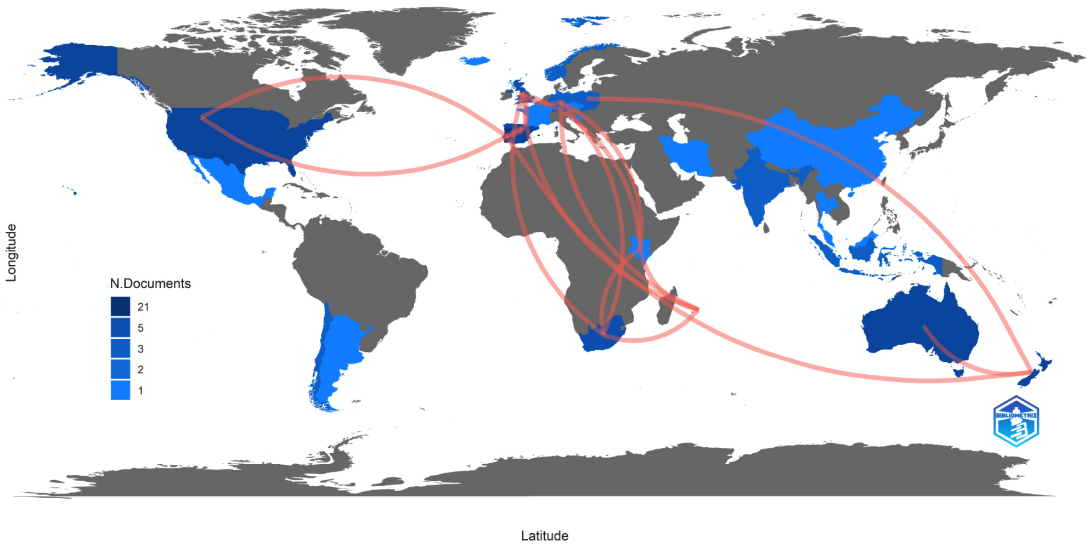


Table 5. Ranking of the most productive institutions

Ranking	Institution	Country	Type	Affiliates	Percentage*
1	University of Aveiro	Portugal	Public	6	4.8
2	University Las Palmas Gran Canaria	Spain	Public	5	4.0
3	University of Trás-Os-Montes and Alto Douro	Portugal	Public	4	3.2
4	Comenius University	Slovakia	Public	3	2.4
5	University of Algarve	Portugal	Public	3	2.4
6	University of Canterbury	New Zealand	Public Research University	3	2.4
7	University of Evora	Portugal	Public	3	2.4

*Note = Calculated percentage of total authors (n = 126)

Figure 4. Geographical and collaborative distribution of scientific production



Leading institutions

Within the ranking of the most prolific institutions (with more than two affiliations), the dominant presence of public universities from Portugal and Spain stands out, with a total of 16 and 5 affiliations, respectively. The most relevant institutions were the University of Aveiro (6), University Las Palmas Gran Canaria (5) and University of Trás-Os-Montes and Alto Douro (4). (Table 5).

Main countries

The results presented in Figure 4 show that the countries with the highest scientific production were, in descending order, Portugal (21), Spain (10), Australia (6) and Kenya (6), confirming the unquestionable leadership of Portugal in the field. Likewise, when examining the contribution between nations, collaborations of Portugal (3) with France, New Zealand and the United States stands out, as well as that of Kenya (4) with Germany, South Africa, Mauritius, and the United Kingdom, and the United Kingdom (5) with Germany, Mauritius, South Africa, Kenya, and Spain.

Most prominent journals

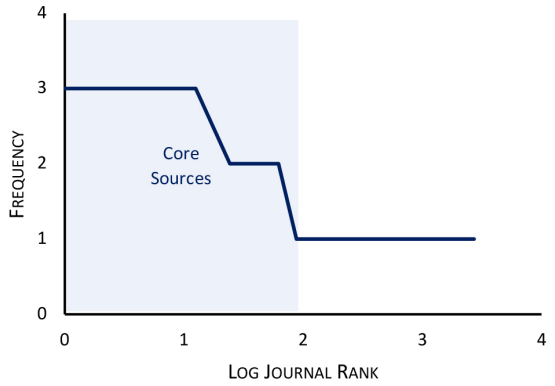
According to Table 6, it can be observed that the journals that have published the most about astrotourism (minimum 2) were from the United Kingdom (5), France (3) and Switzerland (3). The most prominent sources were CAPjournal, Proceedings of the International Astronomical Union, and Sustainability, all with three publications.

A concentrated distribution was identified when examining productivity in relation to publication sources. In particular, when using Bradford's Law (Bradford, 1985), a high degree of correlation (R2= .98) was revealed, indicating that the majority of publications related to astrotourism are found in a small number of journals (Figure 5). For example, the data shows that 33% of scientific production is concentrated in six journals.

Table 6. Ranking of the most productive Journals

Ranking	Title	Articles	Percentage*	TC	Publisher	Country
1	CAPjournal	3	6.7%	1	IAU	France
2	Proceedings of the International Astronomical Union	3	6.7%	1	Cambridge Univ Press	United Kingdom
3	Sustainability	3	6.7%	8	MDPI AG	Switzerland
4	Journal of Tourism and Development	2	4.4%	1	University of Aveiro	Portugal
5	Land	2	4.4%	7	MDPI AG	Switzerland
6	Tourism Management	2	4.4%	49	Elsevier Ltd.	United Kingdom

Figure 5. Bradford's Law



On the other hand, the journal with the highest number of total citations was Tourism Management from Elsevier Ltd. with 49 total citations, followed by Journal of Ecotourism from Taylor and Francis Ltd. with 45 citations and Tourism Management Perspectives from Elsevier USA with 37 citations (Figure 6).

Figure 6. Ranking of the most cited journals

Most cited articles

Weaver (2011) presented the most cited article (45 citations), "Celestial ecotourism: new horizons in nature-based tourism," in which the structure (notion and classification) and magnitude of celestial ecotourism are described. The aim of the study is to encourage its recognition as a relevant field of study and its positioning as an emerging area committed to preserving the skies in tourism. Secondly, with 37 citations, the article "Astronomical Tourism: The Astronomy and Dark Sky Program at Bryce Canyon National Park" by Collison and Poe (2013) stood out, which presents the results of the evaluation of the Astronomy and Dark Sky Program for Bryce Canyon National Park in the United States. Thirdly, with 29 citations, the work of Soleimani et al. (2019) "Astro-tourism conceptualization as a special-interest tourism (SIT) field: a phenomenological approach" stood out, in which astrotourism is conceptualized as a phenomenon of nature-based tourism and presented as a field of special-interest tourism (SIT) using a phenomenological approach. Their study illustrates the potential of astrotourism to develop the image of a tourist destination by combining terrestrial and celestial aspects. Fourthly, the article by Ma et al. (2020) "Special interest tourism is not so special after all: Big data evidence from the 2017 Great American Solar Eclipse" with 25 citations. The study empirically tests an important typology in tourism literature, mass tourism versus special-interest tourism (SIT), revealing that many tourists involved in SIT activities exhibit a characteristic behavior and profile of mass tourists looking for novelty, but aware of the risks and comforts. Finally, with 24 citations, the article by Mitchell and Gallaway (2019) "Dark sky tourism: economic impacts on the Colorado Plateau Economy, USA" highlighted, which examines the economic impact of dark sky tourism in the national parks of the United States in the Colorado Plateau (Table 7).

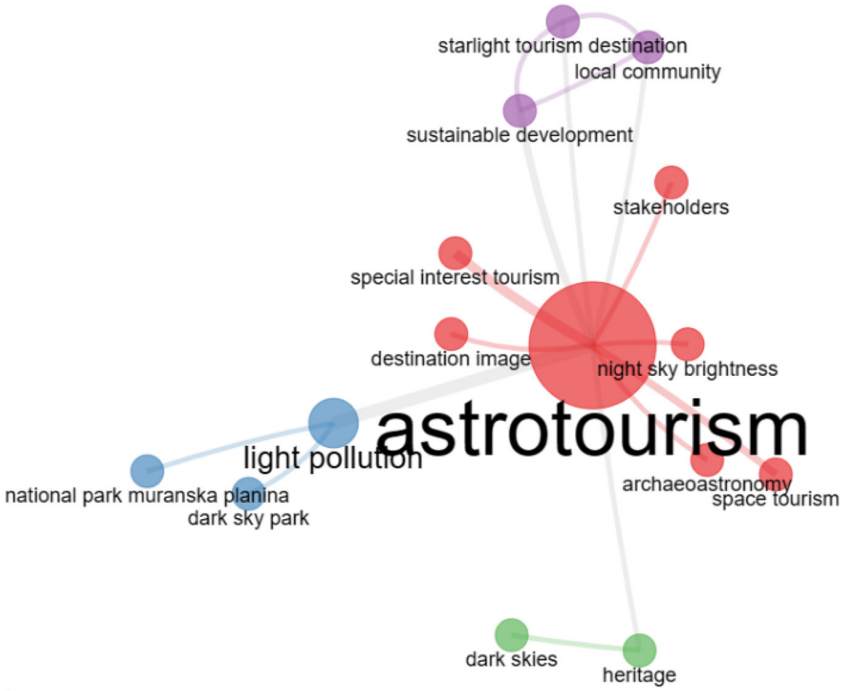
Keyword co-occurrence network

Figure 7 represents the co-occurrence network of author keywords in a bibliometric map, where the size of the nodes

Table 7. Top ten cited articles

Ranking	Article title	Author (year)	Total citations	TC per year
1	Celestial ecotourism: new horizons in nature-based tourism	Weaver (2011)	45	3.46
2	Astronomical Tourism": The Astronomy and Dark Sky Program at Bryce Canyon National Park	Collison & Poe (2013)	37	3.36
3	Astro-tourism conceptualisation as special-interest tourism (SIT) field: a phenomonological approach	Soleimani et al. (2019)	29	5.80
4	Steps to Space; opportunities for astrotourism	Cater (2010)	25	1.79
5	Special interest tourism is not so special after all: Big data evidence from the 2017 Great American Solar Eclipse	Ma et al. (2020)	24	6.00
6	Dark sky tourism: economic impacts on the Colorado Plateau Economy, USA	Mitchell & Gallaway (2019)	14	1.56
7	Aurora Borealis: Choreographies of darkness and light	Jóhannesson & Lun (2017)	14	2.80
8	Functions of Astrofiqh Observatories in Malaysia in Solving Astrofiqh Issues	Ibrahim et al. (2015)	14	2.00
9	To wish upon a star: Exploring Astro Tourism as vehicle for sustainable rural development	Jacobs et al. (2020)	13	3.25
10	Emotions and affects at work on Northern Lights tours	Heimtun (2016)	12	1.50

Figure 7. Keyword co-occurrence network



is proportional to the frequency and relative weight of occurrence, and where the links between different nodes are visualized through lines. Thus, the larger the node, the higher the frequency of its occurrence in the literature. The thicker the connecting line, the greater the thematic link between the two keywords. The central clusters of the map indicate a high interrelation with the basic concepts that make it up, while those located at the edges indicate a low interrelation. The network recorded four central co-words nodes, whose examination of the network centrality

degree confirmed that the term astrotourism is the main source for interaction and linkage with the other keywords of the reviewed articles. In particular, this topic showed levels of intermediation and proximity of 84 and 0.059, respectively, much higher than other concepts, such as light pollution (25 and 0.038) or space tourism (0 and 0.03). This central cluster incorporated six keyword nodes (astrotourism, night sky brightness, special interest tourism, stakeholders, archaeoastronomy, and space tourism) which included three of the four most frequent keywords in the literature: astrotourism (28), light pollution with (8), special interest tourism (4), and space tourism (4).

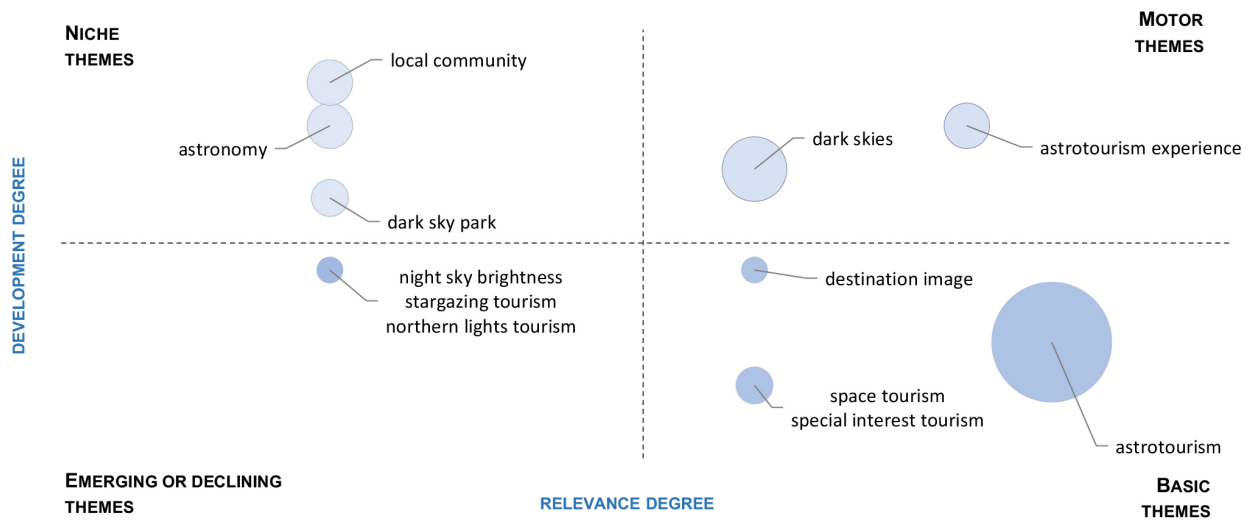
Thematic map of study categories

The thematic map based on the density (development) and centrality (relevance) measures of Callon et al (1991), allowed to determine a total of three clusters with niche themes, highly developed but isolated; two clusters with motor themes, highly developed and relevant; four clusters with basic themes; and three clusters with emerging or declining themes. No clusters with ambiguous or undetermined classification were observed (Figure 8).

Among the three niche-themed clusters, the local community cluster had a total of three publications. The article by Tapada et al. (2021) explores the literature around astrotourism with a qualitative approach, highlighting the main research areas (light pollution, sustainability, and regional development). Additionally, the articles by Tapada et al. (2020) and Tapada et al. (2022) explore the role of stakeholders in value creation in astrotourism projects. Furthermore, their perceptions regarding the development of projects of this kind are evaluated. On the other hand, the astronomy cluster has four articles. Among them, the main theme is sustainable development in the context of rural astrotourism (Jacobs et al., 2020) and nature tourism (Soleimani et al., 2019; Weaver, 2011). In addition, the importance of astronomical outreach is addressed (Char, 2020). Finally, the dark sky park cluster has three articles. The main theme of this cluster is the conservation of natural parks due to its importance for astrotourism (Labuda et al., 2015, 2016) and protection against light pollution (Krajnović, 2020).

The motor themes include two clusters. The dark skies cluster incorporates seven articles. Collison and Poe (2013) evaluate the effectiveness of an astronomical tourism program, with a focus on its positioning and public participation, projecting strategies for its development. Meanwhile, Mitchell and Gallaway (2019) examine the economic impact of astrotourism, mainly through coverage indicators (number of visits) and tourist spending level. The proposal of Li (2021) explores the competitive

Figure 8. Thematic map based on Callon's measures of density and centrality



Note: The night sky brightness, stargazing tourism, and northern light tourism clusters have the same density and centrality measures. That is why they are graphically displayed as a single cluster. The same happens with space tourism and special interest tourism.

advantages of astrotourism, mainly evaluating the intentions to revisit and recommend the destination, elements that allow assessing tourist loyalty (Araya-Pizarro & Verelst, 2021; Yoon & Uysal, 2005). In general, the articles in this cluster investigate the experience and loyalty of astrotourists (Khetrapal & Bhatia, 2022; Pásková et al., 2021). The other motor cluster is astrotourism experience, which includes four articles with similar themes to the previously analyzed group (Li, 2021; Rodrigues et al., 2022). Additionally, the phenomenon of word-of-mouth in astrotourism is explored (Rodrigues et al., 2022) and the effects of destination attributes on tourist satisfaction (Araya-Pizarro, 2020), all around the visitor experience. In general, it is observed that most of the articles in motor clusters are based on primary data on the characteristics of the tourist.

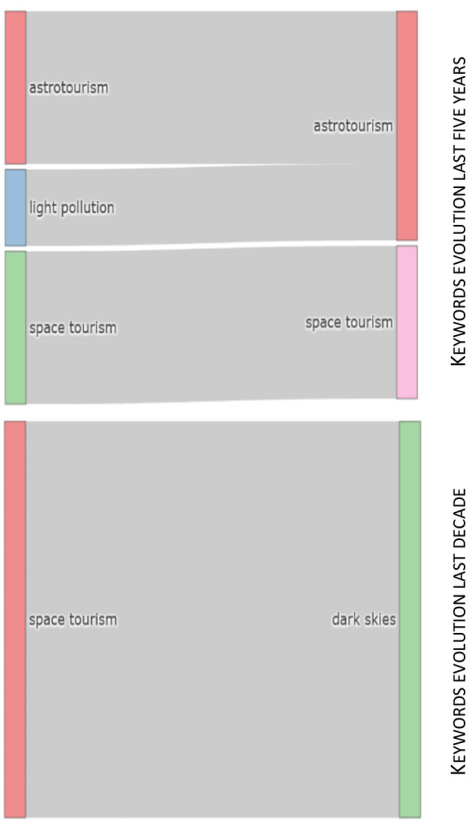
A total of three basic clusters were generated. The astrotourism cluster has the largest number of publications (10), some of which describe and analyze the operation of astronomical centers and observatories for tourism purposes (Hearnshaw, 2016; Ibrahim, 2015), as well as the development and strategic perspectives of astrotourism in particular countries (Priyatikanto et al., 2019; Yuna & Premadi, 2018; Zielinska-Dabkowska & Xavia, 2021). Another motor cluster is destination image, which contains only two articles. The article by Rodrigues et al. (2020) explores how night photographs can contribute to the promotion and strengthening of the image of astrotourism destinations, while the work of Soleimani et al. (2019) analyzes how astrotourism is positioned as a form of special interest nature tourism and how it articulates with the concept of destination image. The space tourism and special interest tourism clusters have two and three articles respectively. The first cluster consists of articles on the development and projections of space tourism (Bógdał-Brzezińska & Wendt, 2021; Cater, 2010). The second focuses on the attributes of the destinations that offer astrotourism services (Joseph et al., 2022; Páramo & Sánchez, 2018). Additionally, the article by Ma et al. (2020) identifies the motivational characteristics of astrotourists and investigates, based on a Big Data study, whether they are more oriented towards mass or special interest tourism. The articles that belonging to basic clusters are mostly descriptive and based on secondary sources (documentaries).

Finally, the declining or emerging themes are classified into three clusters. The first, night sky brightness, contains two articles that study the potential of astrotourism destinations through measurements of sky luminosity (C-Sánchez et al., 2019; Kanianska et al., 2020). The second cluster, stargazing tourism, also has two publications that examine the behavior and preferences (Fernández-Hernández et al., 2022; Li, 2021) of stargazing tourism. The northern lights tourism cluster has two articles. The first explores the emotional factors that affect tourists's decisions to visit northern lights observation sites (Heimtun, 2016). And, the second, analyzes the growth, development and maturity of tourism collaboration networks related to Northern Lights tourism (Heimtun & Haug, 2022).

Trend and thematic evolution

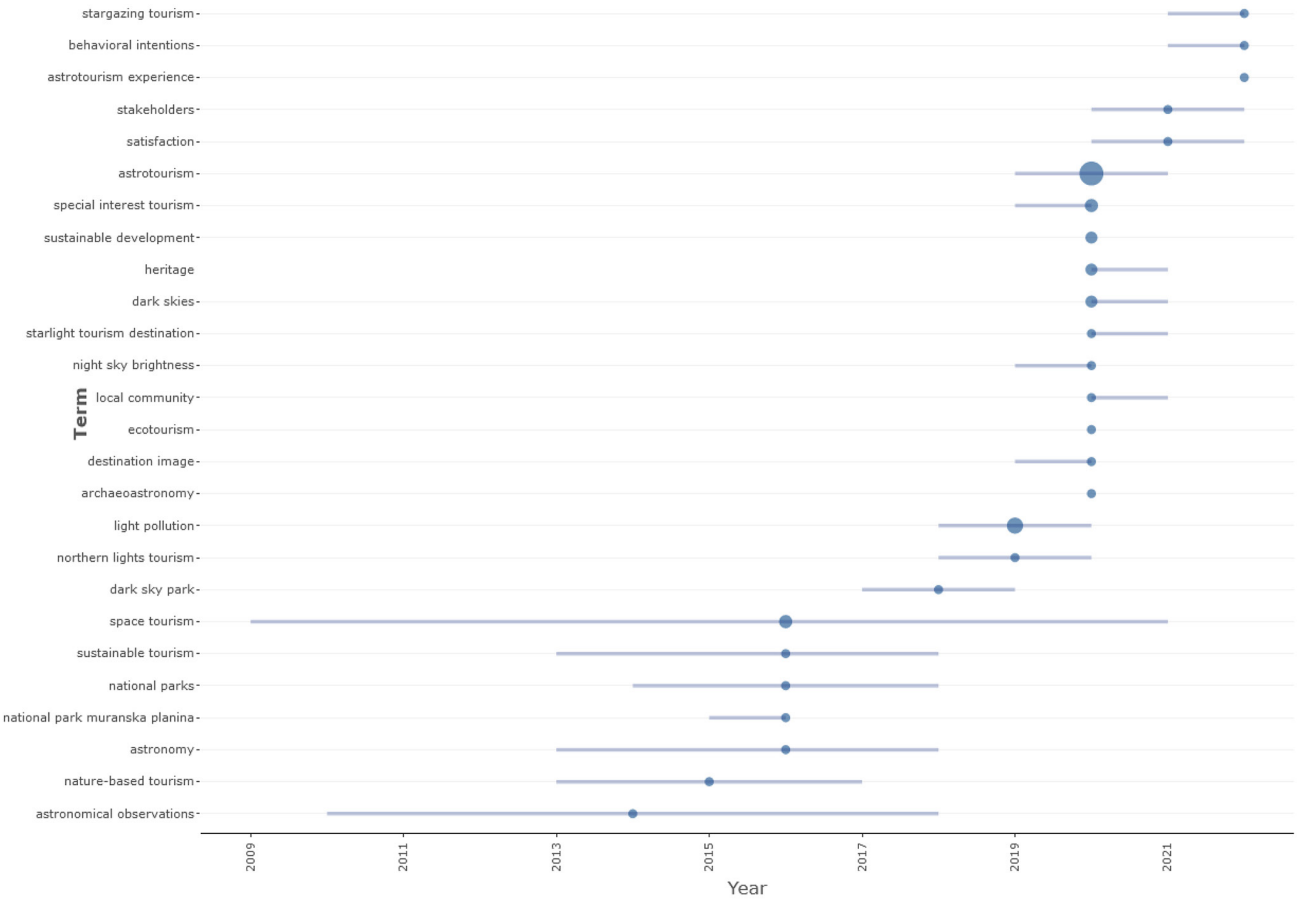
Regarding the evolution of the study topics, the clustering analysis technique based on the proposal of Cobo et al. (2011a) was applied. Two independent analyses were conducted. On one hand, the literature of the last five years (2018 to 2022) was contrasted with that of the previous period. On the other hand, scientific production in the last decade (2013 to 2022) was compared with that of the period between 2007 and 2012 (Figure 9).

Figure 9. Keywords evolution, last five years and last decade



The analysis of the last five years revealed that the use of the concept of light pollution has tended to decrease in astrotourism studies. This could be explained by a greater diversification of the dimensions in which tourist destinations are studied and projected, considering economic, environmental and social factors within the framework of sustainable development. On the other hand, in the studies of the last decade, the use of the concept of space tourism has tended to decrease in favor of dark sky tourism, although it remains a transversal topic in the literature on astrotourism. It is striking that, according to Callon's strategic map (Figure 8), the cluster related to space tourism seems to be in decline. A preliminary hypothesis would suggest that space tourism is becoming an independent topic of study from astrotourism.

This trend is reinforced by reviewing the use of keywords over time in general. It is observed that the use of terms such as space tourism, sustainable tourism, nature-based tourism, and others, is more frequent before 2017, while stargazing tourism, behavioral intentions, stakeholders, satisfaction, sustainable development, among others, are keywords that are used more frequently after that year (Figure 10).



DISCUSION

The purpose of this study was to examine the worldwide scientific production on astrotourism up to 2022. In general terms, the literature on this topic is limited compared to other types of tourism-related work, with continuous production registered from the last decade. However, the study found that astrotourism is an increasingly interest topic, mainly related to recreational and educational activities developed around the cosmos and astronomical phenomena. In this sense, astrotourism has stood out for

offering unique experiences that combine the quality of the night skies with regional infrastructure and other related complementary products (Araya-Pizarro, 2020; Collison & Poe, 2013; Escario-Sierra et al., 2022).

The bibliometric review of scientific production shows a great concentration of publication sources and wide dispersion of authors, whose research is characterized by a collaborative nature and comes mainly from authors of European institutions (Portuguese and Spanish). Among the key concepts reviewed, terms associated with astrotourism, light pollution, special interest tourism, and space tourism stood out.

The thematic analysis of the bibliography reveals highly specialized topics with a high level of development. Among them, the study of stakeholders and their link to the development and prosperity of astrotourism (Tapada et al., 2020, 2022) is highlighted, as well as the importance of sustainable astronomical tourism (Jacobs et al., 2020; Labuda et al., 2015, 2016; Soleimani et al., 2019). On the other hand, the motor themes that drive the development of research on astrotourism are mainly materialized in studies with primary data on tourist satisfaction (Araya-Pizarro, 2020), experiences (Khetrapal & Bhatia, 2022; Pásková et al., 2021) and tourist loyalty, through the intention to revisit and recommend tourist destinations (Li, 2021; Rodrigues et al., 2022). In addition, other articles address the economic impact of astronomical tourism (Collison & Poe, 2013; Mitchell & Gallaway, 2019). Articles on basic themes mostly of research that uses secondary data sources. They include descriptive studies regarding the characteristics of centers, location, and countries that offer astrotourism activities (Hearnshaw, 2016; Ibrahim, 2015; Priyatikanto et al., 2019; Yuna & Premadi, 2018; Zielinska-Dabkowska & Xavia, 2021). In general, articles on motor themes study tourist behavior, while articles on basic themes characterize the destinations where astrotourism is offered.

On the other hand, there are articles with low development and centrality, such as those that evaluate different luminosity indicators as attributes to measure the success of potential tourist destinations (C-Sánchez et al., 2019; Kaniańska et al., 2020). Additionally, the use of concepts such as stargazing tourism and northern light tourism is an emerging trend that is beginning to develop (Fernández-Hernández et al., 2022; Heimtun & Haug, 2022; Li, 2021).

The progressive analysis of the study themes based on the keywords indicates a trend toward increasingly sporadic use of the term "space tourism", while "stargazing" and "dark skies" are used more frequently. The evidence suggests that there is a growing distinction between astronomical observation tourism and space tourism, which raises the possibility of investigating space tourism as an independent topic rather than as a subtopic of astronomical tourism, which would be an extension of the present study in the future. In this line, it is important to mention that, in contrast to space tourism, observational tourism entails the obligation to care for and protect observation sites in a comprehensive manner, which has a positive effect on the development of communities and local entrepreneurship. Consequently, astronomical tourism has a direct impact on sustainable development at the local, regional and national levels; and for this reason, its promotion and positioning is a matter of interest for all the actors in the astrotourism system. On the other hand, the examination of tourist behaviour, satisfaction and loyalty has gained predominance, with a growing number of publications focused on strengthening the competitive advantages of tourist destinations, based on the motivations and profile of visitors.

Finally, the study identifies some limitations and suggestions for future research. Regarding the bibliometric examination, it would be possible to expand the databases and types of documents searched and use additional analysis methods to delve deeper into the structure and dynamics of the research. Additionally, this exploration can be complemented by investigating collaboration networks among authors and institutions. With regard to the results, the findings show that even though research on astrotourism is a topic of great interest, its study is currently limited, especially in terms of its spatial distribution. Therefore, there is a fertile field for future research that considers other disciplinary areas and geographic contexts, which would help enrich the panoramic view of global astrotourism.

CONCLUSIONS

The conclusion is that astronomical tourism is becoming a dynamic topic of study over time. There is a widespread consensus regarding the contribution of astrotourism to regional sustainable development (economic, social and environmental), as well as its ability to educate about the heritage and aesthetic value of the skies, and its focus on creating value for tourists interested in astronomy (motor theme). It is also important to note the relevance of

achieving greater connection between the different actors involved in astrotourism, a topic that is currently underexplored in the literature and considered a research niche. As Jacobs et al. (2020) indicate, the success of astrotourism products development depends largely on the level of destination development and the articulation of the governance systems involved. In addition, future bibliometric studies could explore space tourism as an independent research topic, as conceptually and in practice, it corresponds to particular forms of tourism, which was established with the evolution and trend of the keywords.

It should be noted that this study is the first bibliometric review to uses quantitative clustering techniques (Callon's algorithm) to classify study themes according to their level of interaction and association strength. This has made it possible to identify highly specialized ares (niches), emerging and declining trends, as well as the motor and cross-cutting themes in astrotourism. This approach provides a more accurate vision of the research landscape, which can serve as a guide for future work and discoveries in this field of knowledge.

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