Design, implementation and evaluation of transnational collaborative programmes in astronomy education and public outreach

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IV

Impact of Astronomy Education and Public Outreach on Astronomical Research

IV.1

A Survey of Astronomical Research: A Baseline for Astronomical Development

Measuring scientific development is a difficult task. Different metrics have been put forward to evaluate scientific development; in this chapter we explore a metric that uses the number of peer-reviewed, and when available non- peer-reviewed, research articles as an indicator of development in the field of astronomy. We analysed the available publication record, using the Smithsonian Astrophysical Observatory/NASA Astrophysics Database System, by country affiliation in the time span between 1950 and 2011 for countries with a gross national income of less than 14,365 USD in 2010. This represents 149 countries. We propose that this metric identifies countries in "astronomical development" with a culture of research publishing. We also propose that for a country to develop in astronomy, it should invest in outside expert visits, send its staff abroad to study, and establish a culture of scientific publishing. Furthermore, we propose that this chapter may be used as a baseline to measure the success of major international projects, such as the International Year of Astronomy 2009.

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1. Introduction

Astronomy is a fascinating subject, with a unique ability to inspire and to stimulate curiosity in human beings about the wonders of science and technology. This makes astronomy a useful tool for bringing science to the general public to inspire, to show the scientific method, and to open their eyes to a new perspective. Astronomy has been shown to have wide-reaching applications in many different sectors of society. Immediate examples are the technological developments that came from the building of the ESA/NASA Hubble Space Telescope,[1] such as the use of mirror technology to increase semiconductor productivity and performance, and CCD technology being adapted for more efficient biopsies[2] (Astronomy & Astrophysics Survey Committee 2001). These examples demonstrate that astronomy not only aims to answer fundamental questions about how the universe works and to stimulate curiosity, but it can also aid technological development and economical growth. Although it is difficult to quantify the return of investment in astronomy, some reports show spin-off technological development to return as much as ten-to-one.[3]

One project that aimed to stimulate and inspire people's curiosity with the wonders of the universe was the International Year of Astronomy in 2009 (IYA2009). This project reached over 815 million people in 148 countries (Russo & Christensen 2010) through various activities from star parties and school programs to the use of IYA2009 to launch university programs (e.g., Ribeiro et al. 2011). The success of IYA2009 was no mean feat. However, truly understanding and evaluating its impact, at least in astronomy, will be a difficult task. Project evaluations are applied for numerous reasons,[4] for example, (1) to determine if the project goals were reached, (2) to obtain information on the outcomes of an event, along with suggestions for improvement, (3) to identify the changes resulting from the implementation of a project, (4) to identify ways in which the project could have been more effective and efficient, (5) to identify unexpected results, (6) to crystallize ideas about the event and what it is intended to achieve, and (7) to provide encouragement by demonstrating that efforts have been worthwhile. Measuring this impact may be done in various forms.

Developing Astronomy Globally (DAG), a cornerstone project of IYA2009 which was fed into the International Astronomical Union (IAU) Strategic Plan,[5] was designed to develop astronomy professionally (at universities and at the research level) worldwide.6 As part of DAG, a survey was conducted as a self-evaluation of the countries participating in IYA2009 (Naicker & Govender 2009). The survey was completed by the IYA2009 Single Point of Contact from each country and therefore may suffer some bias and the data may be incomplete. Naicker & Govender (2009) proposed that each country would fall into one of four separate phases of astronomical development, and presented some recommendations for development accordingly. In summary, these phases were (1) well established, (2) in need of support, (3) nonexistent with strong potential, and (4) non-existent with limited potential.

Hearnshaw (2007) extracted statistical information from the Smithsonian Astrophysical Observatory/NASA Astrophysics Data System (hereafter ADS) to obtain an overview of the state of astronomical development for each country. Hearnshaw found that the number of publications per IAU member correlates strongly with gross domestic product (GDP) per capita. However, this concentrated only on IAU member states and a select few non-member countries. This chapter looks at a sample of peer-reviewed research articles for a number of countries, most not included in Hearnshaw (2007), to measure countries in astronomical development and to identify those with a culture of publishing using ADS, which is used by the entire astronomical community (Henneken et al. 2009), and is therefore a good database for determining the astronomical research being carried out throughout the world. Other means are possible for this study, e.g., the World of Science. However, two major factors played a role in the decision to use ADS instead: (1) it is free and (2) as mentioned above, it is used by the entire astronomical community. From this viewpoint, counting the number of publications in astronomy by each country provides, to a first approximation, a good indicator of astronomical development.

Due to the sheer amount of data and different sociological reasons for a country to be in astronomical development, we only concentrate on providing a quantitative, rather than qualitative, discussion and invite the community to draw their own conclusions for their particular regions.

2. Methods

When publishing in a refereed journal, authors are required to provide their institution address with the article. In the majority of cases this is also indexed for searching, alongside coauthors, title, and other key information that makes searching for a journal article simple. We therefore used the ADS affiliation field to count astronomical publications by country from 1950 up to and including 2011. We only queried the astronomical database for these studies. However, this query returns journals not only related to astronomy but also to the geosciences. Particular care was taken for countries that may conflict with other words in the affiliation. For example, Niger is easily confused with Nigeria and Guinea is easily confused with Equatorial Guinea, Guinea-Bissau, and Papua New Guinea. The search returned the number of papers for each country in a given year. We then selected papers, based on the biased view of the authors, that we consider to be in mainstream astronomical journals. These were The Astronomical Journal, Astronomy and Astrophysics, The Astrophysical Journal (including Letters and Supplements), Monthly Notices of the Royal Astronomical Society, New Astronomy (including Reviews), and Physical Reviews. The first four journals were described by Henneken et al. (2009) as the core journals read regularly by active astronomers. We searched, using the ADS Mighty Search,[7] both refereed and non-refereed papers, although the latter are very difficult to quantify due to the fact that, in the majority of the cases, the affiliations are not given in the ADS abstract. Furthermore, counting the number of papers per country was based solely on whether the country name appeared in the affiliation field. As an example, in the current chapter each of the countries in the affiliation field would receive a count of one paper. This is not uncommon in astronomy, where 55% of papers are suggested to arise from authors from different countries (Abt 2007).

The number of papers published per year was used to identify which countries are in astronomical development. The selection of countries we considered was based on their gross national income (GNI).[8] We considered those countries that have a GNI of less than 14,365 USD (based on the average world GNI for 2010).We should note that a country's GNI can be very dynamic. However, for the purpose of these studies, just considering the 2010 number is sufficient for the majority of the world's countries. This search retrieved 149 countries (Appendix A), including all the least developed countries (LDCs; Appendix B).

3. Results

Figures 1–6 show the results for the number of papers per year, as well as the GNI per country per year, divided into Africa, South and Latin America, Asia, Europe, Oceania, and LDCs, respectively. Thewhite histograms are all of the results as queried on ADS while the black histograms are for the selected mainstream astronomical journals, as mentioned above. Only countries with paper counts greater than five in total are shown in the figures, while excluded countries are shown in Table 1 along with their total number of papers in brackets. Furthermore, only the time span from 1970 onward is shown, as before this date the number of papers is generally very low and will not aid our discussions.

Table 1. Countries with Five or Fewer Publications Over the Time Span of Our Studies. The number in parentheses is the number of publications.

Country	**Country**	**Country**
Afghanistan(1) Angola(2) Anguilla(0) Antigua and Barbuda(0) Belize(1) Bhutan(1) Burundi(2) Cambodia(1) Cape Verde(3) Central African Republic(2) Chad(1) Comoros(0) Cook Islands(1) Cote d'Ivoire(0) Djibouti(3) Dominica(0) Dominican Republic(2)) DPR Korea(3) El Salvador(4) Equatorial Guinea(0)	Gabon(2) Gambia(0) Georgia(0) Grenada(2) Guatemala(5) Guinea-Bissau(0) Guinea(0) Guyana(1) Haiti(2) Kiribati(0) Kosovo(4) Lao(0) Liberia(0) Madagascar(2) Malawi(1) Maldives(0) Mali(0) Marshal Islands(1) Mauritania(1) Micronesia(1)	Mozambique(3) Nauru(0) Niger(0) Palau(1) Rwanda(1) Saint Kitts and Nevis(0) Saint Vicent and the Grenadines(0) Samoa(2) São Tomé and Principe(0) Seychelles(1) Sierra Leone(1) Solomon Islands(3) Somalia(4) Suriname(0) Timor-Leste(0) Togo(0) Tonga(0) Tuvalu(0) Vanuatu(1)

We only considered results from the astronomical database within ADS, which also retrieves articles from the field of geosciences. The search did not

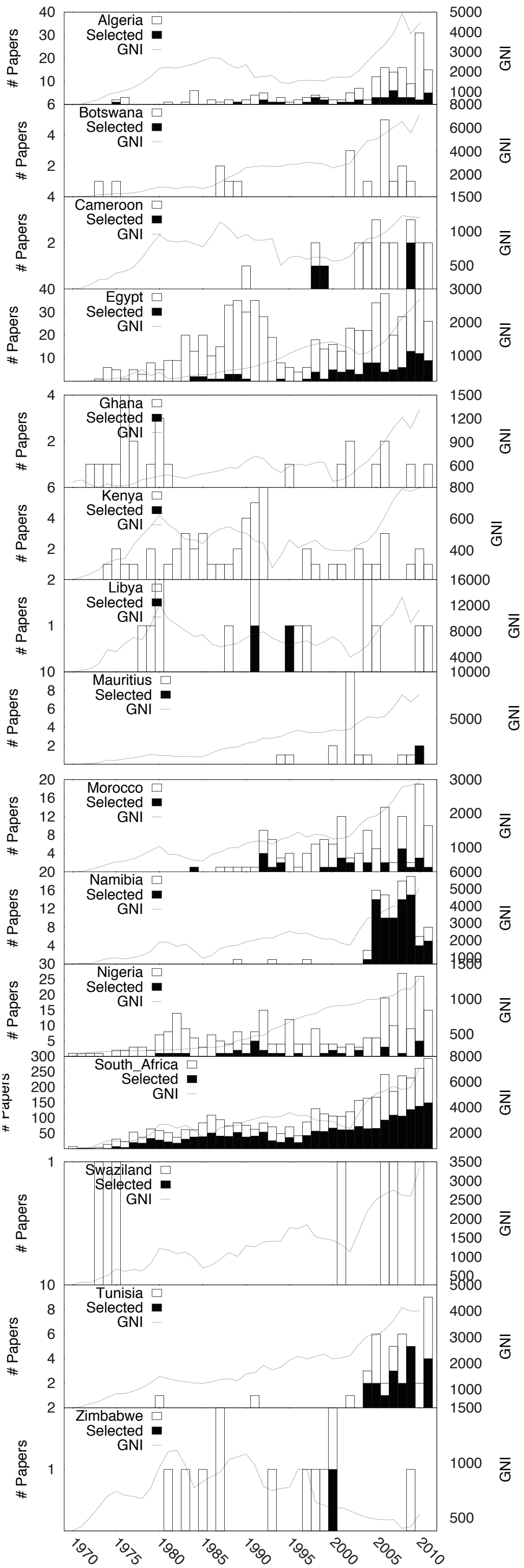
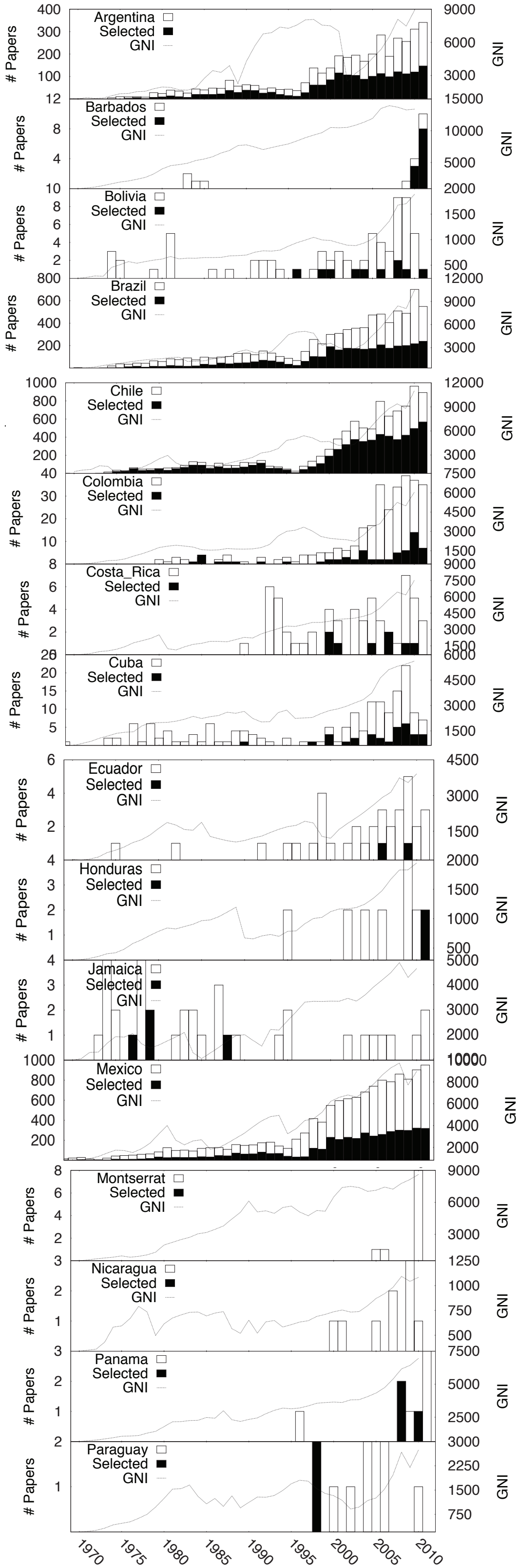


Figure 1. Results for the African continent. Shown are all the results from the ADS search (white histograms) along with the journals identified as mainstream (black histograms), and for comparison, the country's GNI (dashed line).



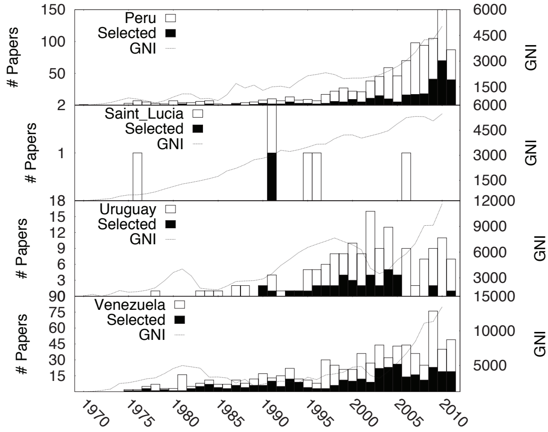


Figure 2. As Figure 1 but for South and Latin America.

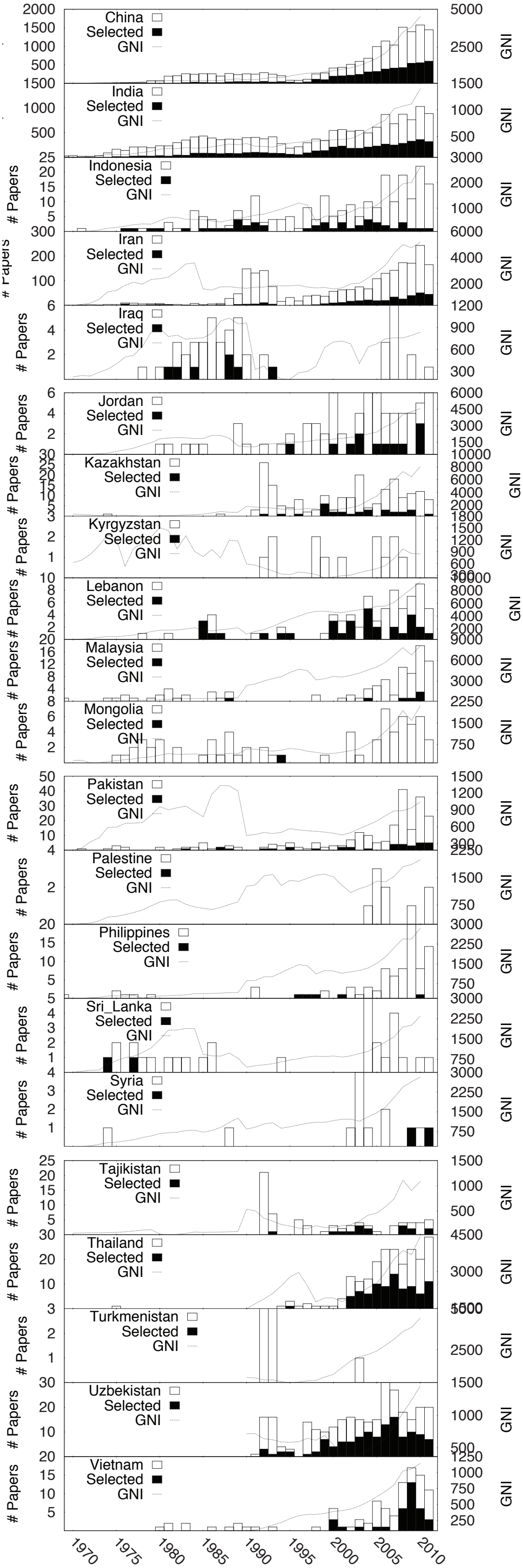


Figure 3. As Figure 1 but for Asia.

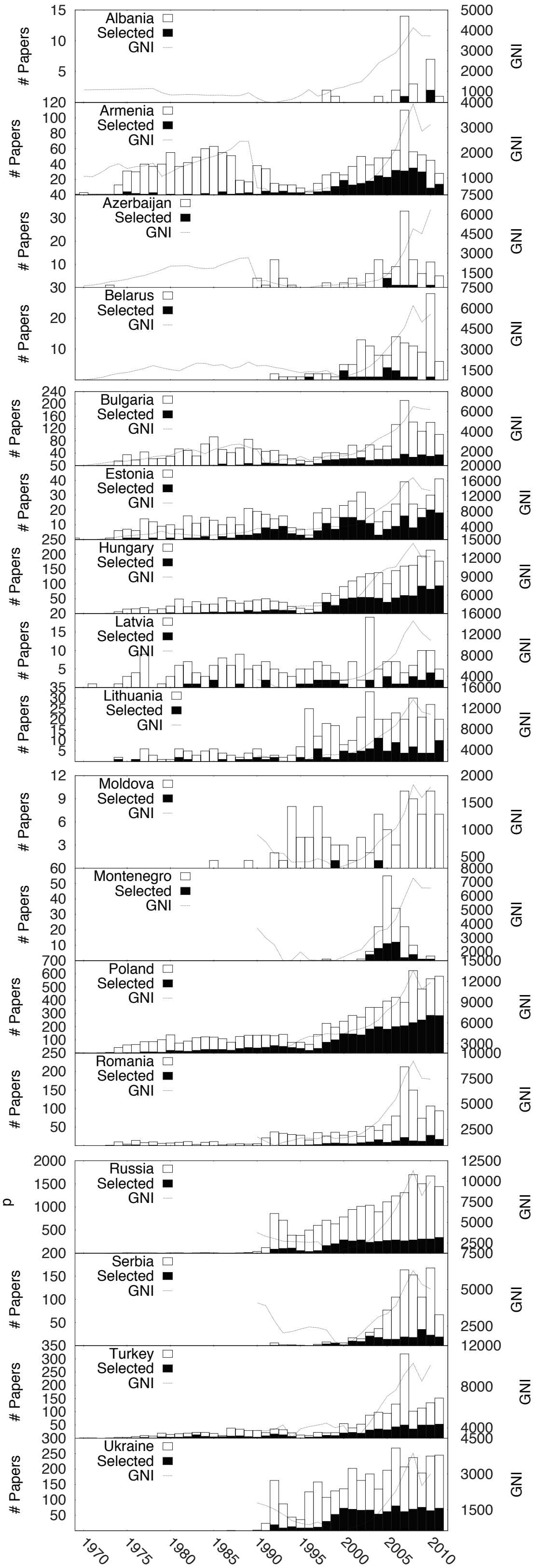


Figure 4. As Figure 1 but for Europe.

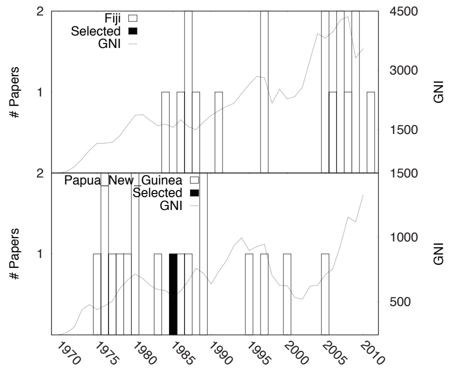


Figure 5. As Figure 1 but for Oceania.

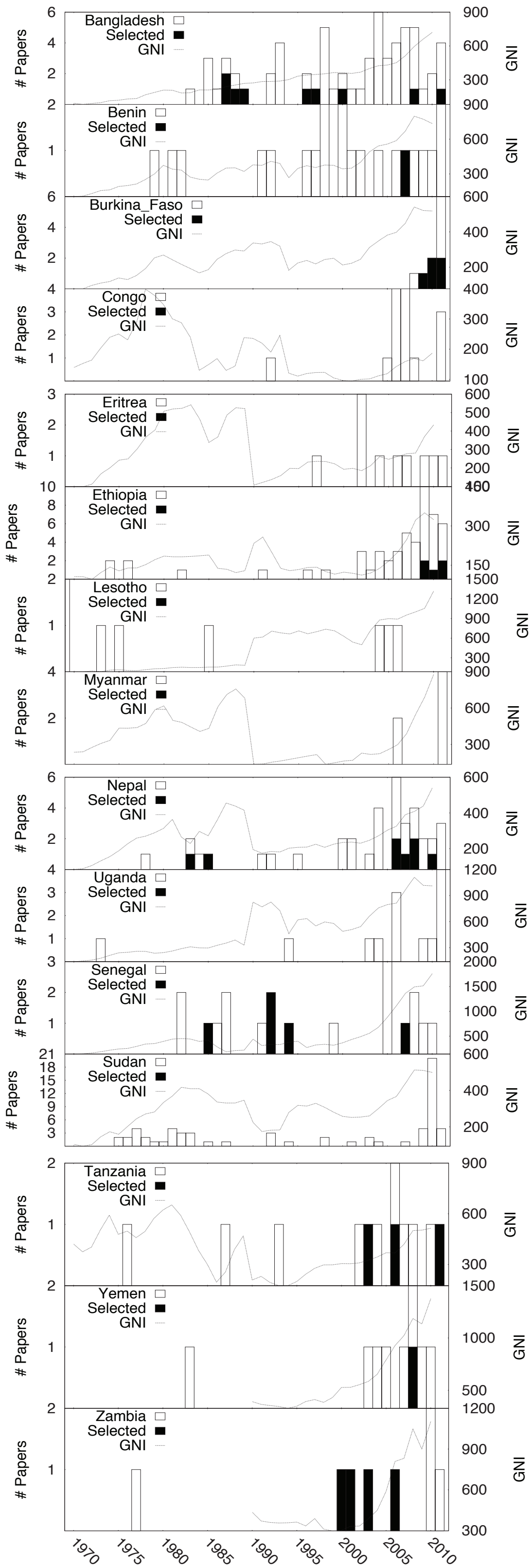


Figure 6. As Figure 1 but for the LDCs.

include results from the physics database query within ADS, which would undoubtedly increase the number of publications for any given country. Several descriptions can be made upon visual inspection of Figures 1–6, which fall into five general categories that may complement the phases described by Naicker & Govender (2009), described below:

1. Countries with a history of publishing research articles, both in astronomy and other sciences.
2. Countries with a history of publishing in refereed journals, not including astronomy.
3. Countries where the majority of research output is in astronomy.
4. Countries with little history of research publishing.
5. Countries that are difficult to place in the categories above, either due too little information and/or recent publishing activity.

4. Discussion and Conclusion

Based on the general descriptions above,most of the countries in Europe have a good history of publishing both in astronomy and other sciences, while in Africa it is difficult to say anything quantitatively except in the cases of Egypt, Namibia, and South Africa. In terms of the LDCs, more investment should be made in the general sciences and the culture of publishing. The Asian continent presents some interesting results, with countries like China and India that have a good history of publishing, both in astronomy and other sciences, and emerging countries like Thailand and Uzbekistan that publish very few papers in any of these fields. In South and Latin America, many countries have a history of publishing in both astronomy and other sciences, for example, Argentina, Brazil, Chile,Mexico, Peru, and Venezuela. Emerging countries with potential for developing astronomy further, due to an already existing culture of publishing, include Colombia and Uruguay.

We believe that the most successful country in developing astronomywill be one that already has a culture of publishing. In a number of countries, there appears to be a correlation between the country's GNI and the number of published papers. This may be related to an overall investment in science and technology, via job creation and making a country attractive to foreign scientists who may bring their expertise. To put this in the context of major projects such as the IAU Office of Astronomy for Development,[9] we believe that for a country to be successful in developing astronomy, within the lifetime of the office it should have a well-established publishing record (not necessarily in astronomy) or invest in bringing in outside expertise, which can play a leading role in implementing courses at universities to help push for more papers to be published. One immediate example is that of Burkina Faso, where the University of Ouagadougou partnered with the University of Montreal in 2006 to develop an astronomy degree and build an observatory (Carignan et al. 2011). Also, a level of investment from the country in science and technology would improve the culture of publishing and encourage individuals to disseminate their research and think critically about others' research. Similarly, Bilir et al. (2012) outlined Turkish astronomical output from 1980 to 2010, with further information about their astronomical community, including the impact of their publications. However, examples where an ethical conundrum about acquiring foreign expertise can be interpreted as a means of exchange for academic prestige (Bhattacharjee 2011, see also the various comments about the article online and in Science Magazine on 2012 March 02) tell us more about how impact factors guide general research foundations in funding an institution and/or individual. Indeed, no metric is foolproof, and important strides are being done by various groups.[10,11,12]

Education and Public Outreach (EPO) programs both on global scales, such as the IYA2009, and locally can play a key role in the development of astronomy in a country. For example, Mozambique used the momentum of the IYA2009 to develop local EPO programs and as a launching platform to develop astronomy at the university level (Ribeiro et al. 2011). Similarly, with the future construction of the Square Kilometer Array, decided between Australia and New Zealand, and South Africa and its partner countries (Botswana, Ghana,Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia), the African continent is gearing up for the construction of an African Very Long Baseline Interferometer.[13]

In future work we would like to quantify the role each country has played on paper, as a means to determine “leadership.”Afirst indication, as mentioned above, is that a few of the countries are not leading any projects. However, we should determine what leading really means. In the era of large projects we find more and more author lists in alphabetical order, while normally the first author is the person who has played a leading role in the research. For example, the Research Excellence Framework[14] in the United Kingdom, requests that for papers with more than 10 authors, the author should explain what their contribution to the paper was regardless of whether or not they are the first author. No justification is required if the paper has fewer than 10 authors. We only concentrated on the number of published papers to identify the global level of astronomical development. However, the ADS system has a number of other outputs that may be used for various studies, for example, the number of citations, the number of authors, and their collaborations (e.g., Newman 2001). This may also be an interesting project to visualize research collaborations.[15]

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Miley, and Robert Simpson. We thank the anonymous referee for constructive comments on the original manuscript.

Appendix A: World Countries

The countries listed below are those considered for this study. These decisions were made based on a GNI of less than 14,365 USD in 2010. Those in italic are the LDCs (see also Appendix B).

Africa: Algeria, *Angola, Benin*, Botswana, *Burkina Faso, Burundi*, Cameroon, Cape Verde, *Central African Republic, Chad, Comoros*, Cote d'Ivoire, *Democratic Republic of the Congo, Djibouti,* Egypt, *Equatorial Guinea, Eritrea, Ethiopia*, Gabon, *Gambia*, Ghana, *Guinea, Guinea-Bissau,* Kenya, *Lesotho, Liberia,* Libya, *Madagascar, Malawi, Mali, Mauritania*, Mauritius, Morocco, *Mozambique*, Namibia, *Niger*, Nigeria, *Rwanda, Uganda, São Tomé and Principe, Senegal,* Seychelles, *Sierra Leone, Somalia*, South Africa, *Sudan*, Swaziland, *Togo, United Republic of Tanzania,* Tunisia, *Zambia*, Zimbabwe.

Asia: *Afghanistan, Bangladesh, Bhutan*, *Cambodia*, China, Democratic People's Republic of Korea, India, Indonesia, Iran, Iraq, Jordan, Kazakhstan, *Kiribati*, Kyrgyzstan, *Laos*, Lebanon, Malaysia, Maldives, Mongolia, *Myanmar, Nepal*, Pakistan, Palestine, Philippines, *Samoa, Solomon Islands*, Sri Lanka, Syrian Arab Republic, Tajikistan, Thailand, *Timor-Leste*, Turkmenistan, *Tuvalu*, Uzbekistan, *Vanuatu*, Vietnam, *Yemen*.

Europe: Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, Georgia, Hungary, Kosovo, Latvia, Lithuania, Moldova, Montenegro, Poland, Romania, Russian Federation, Ukraine, Serbia, Turkey.

Latin America: Anguilla, Antigua and Barbuda, Argentina, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, *Haiti*, Honduras, Jamaica, Mexico, Montserrat, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Uruguay, Venezuela.

Oceania: Cook Islands, Fiji, Marshall Islands,Micronesia, Nauru, Palau, Papua New Guinea, Tonga.

Appendix B: Least Developed Countries

The concept of LDCs represents the poorest and weakest segment of the international community.[16] The list includes 48 countries: 33 in Africa, 14 in Asia and the Pacific, and 1 in Latin America. In 2003, the Economic and Social Council of the United Nations used the following three criteria for the identi-

fication of the LDCs, as proposed by the Committee for Development Policy (CDP).
1. A low-income criterion, based on a three-year average estimate of the GNI per capita based on the World Bank Atlas method (under 992 USD for inclusion, above 1190 USD to be removed from the list).
2. A human resource weakness criterion, involving a composite Human Assets Index based on indicators of (1) nutrition, (2) health, (3) education, and (4) adult literacy.
3. An economic vulnerability criterion, involving a composite Economic Vulnerability Index based on indicators of (1) the instability of agricultural production, (2) the instability of exports of goods and services, (3) the economic importance of non-traditional activities (share of manufacturing and modern services in GDP), (4) the merchandise export concentration, and (5) the handicap of economic smallness (as measured through the population in logarithm) and the percentage of population displaced by natural disasters.

To be added to the list, a country must satisfy all three criteria. To qualify for graduation, a country must meet the thresholds for two of the three criteria in two consecutive triennial reviews by the CDP. In addition, since the fundamental meaning of the LDC category, i.e., the recognition of structural handicaps, excludes large economies, the population must not exceed 75 million.

Notes

[1] http://spinoff.nasa.gov last accessed 2012 November 02.
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