



Space Physics Career in a Developing Country: Opportunities and Challenges

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The development of an infrastructure of observational instruments is a great challenge for any young scientist especially working in a country where the infrastructure addresses a new field of scientific knowledge and the funds are limited. However, I argue that although it can be questionable in terms of all the difficulties that you might face, the observational infrastructure is a crucial aspect of building a local scientific community. Therefore, it should be pursued as a national priority.

Keywords: space weather, observational networks, solar storms, real-time data, radiotelescope

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1 INTRODUCTION

I am from Mexico. My country is located in North America and shares a border with the United States of about 3,152 km. There are significant differences concerning wealth and development between the two countries. Although that Mexico has the 15th largest economy in terms of its Gross Domestic Product (GDP), there are many aspects where the country requires more progress. One of them is its investment in science and technology. Whereas the US has a GDP some 20 times larger than that of Mexico, NASA has a budget that is about six orders of magnitude greater than the Mexican space agency. Therefore, to advance a space program, Mexico requires a significant increment in funding by the government.

I did my bachelor's science degree at the National Autonomous University of Mexico (UNAM in Spanish) with a thesis on interplanetary shock waves (1985–1991). My advisor was Dr. Silvia Bravo. Then I was fortunate to obtain a scholarship for my Ph.D. at Imperial College, University of London (1991–1995). My doctoral thesis examined magnetic field data from Ulysses, the most exciting heliospheric mission at that moment. Ulysses was the first spacecraft measure the out-of-ecliptic solar wind *in situ*. My focus was on the analysis of the heliospheric shock waves detected during the first part of the mission (1990–1994) (Balogh et al., 1995). My adviser was Professor André Balogh. When I finished my doctorate, I got a postdoctoral fellowship at the Jet Propulsion Laboratory NASA-CalTech (1995–1997), where I continued my research on interplanetary shocks. My adviser was Dr. Ed Smith, and I also had the opportunity to collaborate with Dr. Marcia Neugebauer, the head of the group at that moment (González-Esparza et al., 1996). I had accomplished a good early career as a young scientist in heliospheric physics, but eventually I had to decide whether I return to my country or continue working abroad. I was happy and proud to work at JPL-NASA, but I missed my family and culture. I wanted to proceed with a career as a professional scientist, and, in that respect, staying in the United States would probably be one of the best options. However, the essential thing in my decision was that I had received a Ph.D. grant from Mexico, and I had the moral commitment to return to my alma mater.

In 1997, I returned to Mexico and incorporated as a researcher at UNAM. Only one group in Mexico studied space physics. It consisted of six members each of whom pursued his or her area



FIGURE 1 | Site of the Mexican Array Radio Telescope (MEXART), main observatory of the Space Weather National Laboratory (LANCE acronym in Spanish).

of research within space physics. Unfortunately, there were personal issues within the working group (a common problem in the academic environment everywhere), and the working atmosphere was not the best when I arrived. I began collaborating with my former advisor. Dr. Silvia Bravo was pursuing a project to build an Interplanetary Scintillation (IPS) array in Mexico. The idea was to construct a radio telescope similar to that of Dr. Antony Hughes's group during the late sixties-seventies in Cambridge, United Kingdom. This group discovered the IPS phenomenon. By using IPS observations from a ground-based radiotelescope, it is possible to infer some solar wind properties (speed and density fluctuations). The IPS technique provides a source of solar wind information, and it becomes a good option when no other instruments are available.

Dr. Silvia Bravo passed away due to cancer in 2000. From that moment, I had the full responsibility to accomplish the project. This IPS project was difficult for us in many respects: I had a poor expertise in managing scientific projects, we lacked an experienced technical workgroup in radio astronomy, and the funding was partial and limited. Learning basic radioastronomy, the principles of the instrument, and struggling to get support and funding in Mexico, did not seem very promising for a good career in Frontier science in space physics at that moment. Rather the straightforward strategy would be to maintain my research collaborations with the Ulysses' scientific team. How many years would we need to invest in getting some valuable IPS scientific data? If I knew it would take us 20 years to do it, I might have taken the former straightforward option. Fortunately, I did not know.

There was also a national pride in the project; we would have our solar wind data. However, the "establishment" of the scientific community in Mexico did not necessarily agree with

this idea of developing an observational infrastructure to study solar wind parameters. The "mainstream" philosophy was that the scientific research at UNAM should be based on state-of-the-art international instruments, whose data had become more accessible via internet and the open-access policies for data of international instruments including the important NASA missions. With lack of the human resources and technical expertise, did it make sense to spend time, funding, and effort developing our incipient instrument?

In Mexico, the academic production of a researcher was evaluated mainly by his or her participation in a number of published papers in the indexed journals. The university pays the basic salary, but a substantial part of the income comes from "stimuli" by the government. The "stimuli" are rated and evaluated every 3 years by academic commissions. These evaluations also count in teaching and popularizing science activities, but the main factor is number of articles published. The development of scientific infrastructure counted as well, but as a secondary activity. These ratings are questionable in terms of the country's priorities, and they have been reviewed recently. Developing the country's observational infrastructure should be one of the most significant achievements.

We began construction of the Mexican Array Radio Telescope (MEXART) in the state of Michoacan (about 400 km from Mexico City) (**Figure 1**) (González-Esparza et al., 2004). It was a difficult beginning. We made several technical errors that we could have avoided with more knowledge and experience. However, this was the learning path. The partial and limited funding obliged us to work dividing the project in stages and extended the duration of the array's construction for several years. It was not easy to get technical assistance from the United States without funding, so we had to look for collaborative help from elsewhere. We are very grateful to Professor Shri

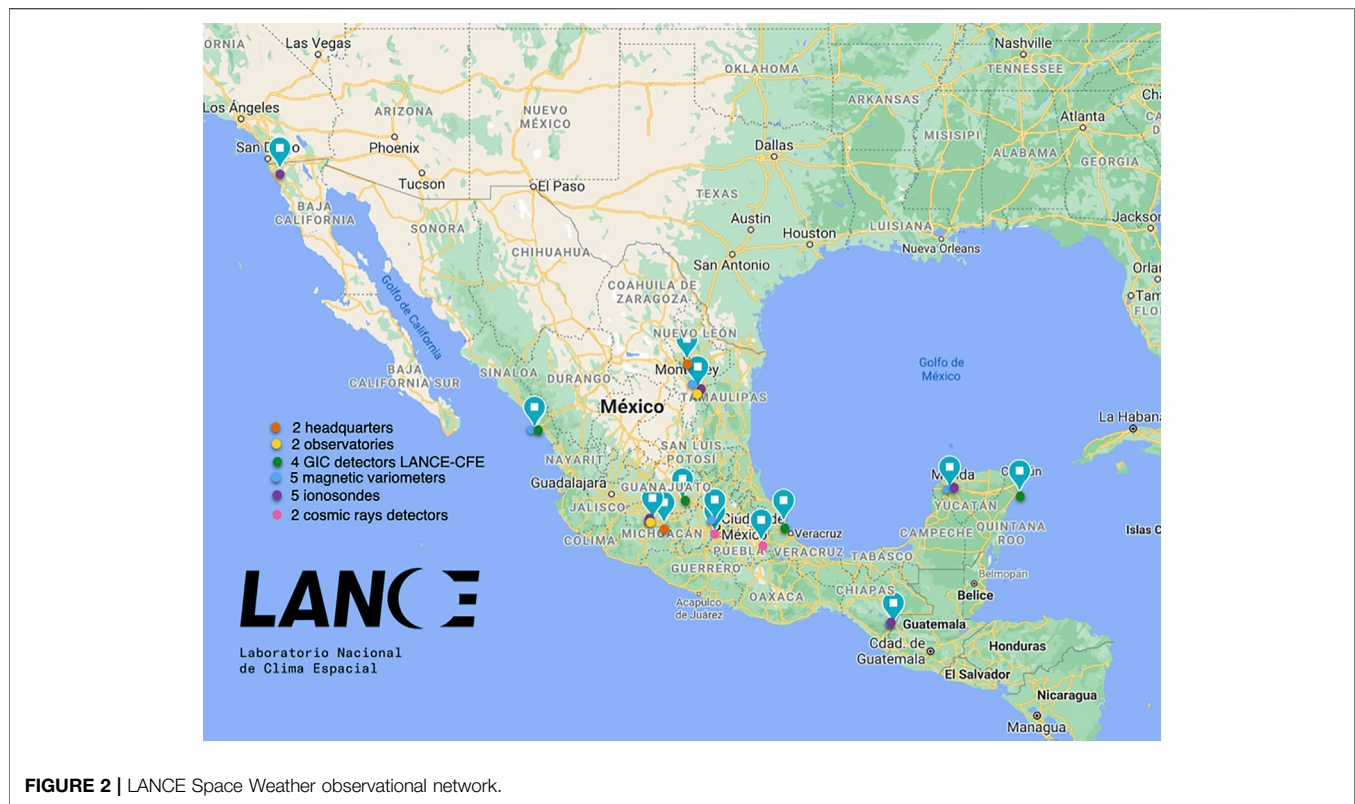


FIGURE 2 | LANCE Space Weather observational network.

Ananthkrishnan and the engineers from his working group sent to Mexico from India's National Centre for Radio Astrophysics, Tata Institute of Fundamental Research. Their expertise in radioastronomy techniques, and their generous support, were crucial for the beginning of the project. We also established a collaboration with the Institute of Geophysics and Astronomy of Cuba whose engineers assisted in construction and testing the array. One of the lessons learned was that we could get assistance from the international community if we looked and asked for it.

Soon it became clear that I could not manage the MEXART project remotely from Mexico City. Therefore, in 2006 my family and I moved to live near the site. In addition, I initiated a new life on a new UNAM campus in Morelia to form a new space physics group.

In 2014 the legislators modified the General Protection Law in Mexico and included Space Weather events in the list of natural hazards that the National Civil Protection System must attend. At that moment, we saw an opportunity for our group in Morelia to grow and begin a new research area, assisting the authorities in accomplishing the law's mandate concerning solar and geomagnetic storms. We created the Mexican Space Weather Service (SCIESMEX acronym in Spanish) at the Institute of Geophysics-UNAM. We began to interact with the Civil Protection System providing an early warning of Space Weather events (Gonzalez-Esparza et al., 2017).

The experience and expertise we got from the construction of MEXART would let us propose a project aiming to develop a set of new observational networks that would include solar,

interplanetary, geomagnetic, ionospheric, and cosmic ray phenomena. These networks of instruments are to provide the regional data on Space Weather conditions in Mexico (Figure 2). Considering the urgent need for these data and its analysis, we established in 2016 the National Space Weather Laboratory (LANCÉ by its acronym in Spanish). One of the main issues that we claimed in our proposal was that Mexico did not have an observational infrastructure to study regional effects of Space Weather. We lacked data on geomagnetic field and ionospheric phenomena; nor did we have data to analyze the national electric system's vulnerability to geomagnetic storms. In addition, there are no historical records to study benchmarks of Space Weather phenomena in Mexico. We saw in this problem an opportunity and began to submit projects to our research council to cover this lack of essential infrastructure.

It has become an increasing necessity for the scientific community to justify funding from public funds in recent years. In addition, governments and legislators are demanding that the scientific community be involved in national priorities. This subject can be controversial within our community. We must defend the importance of fundamental research. However, the Space Weather investigations provide an opportunity to work on fundamental problems in space physics and several applications for society. The recent broad interest in the Space Weather by the international community, not only academia but also the governments and industry, triggered opportunities for the space physics community. This is

excellent news in the countries where there is still a lack of Space Weather studies. The state entities in different countries realize the importance of these investigations and might open support possibilities. In addition, the promotion of collaborative efforts in Space Weather by United Nations organizations such as UNOOSA, WMO, ICAO, UNDRR, Etc., have bridged excellent opportunities to obtain local funding.

Based on my experience, I would give the following advice for the successful development the scientific instrument infrastructure in the countries where it is still lacking.

1.1 Opportunities

- Each country needs to develop strategic areas in scientific research.
- The governments need to support the establishment of observatories and instrumental networks to obtain regional information and manage its data. It is about national sovereignty.
- Space Weather needs provide an excellent opportunity to begin a project involving basic scientific research and influence areas of national security. It should be emphasized that the subject necessarily requires the development of observational facilities and interdisciplinary working groups.
- Look for international assistance. People in science are united by scientific interest. It is a community in which one is usually open to shaking hands with another. Researchers make strong friendships with each other, even between researchers from different countries.

In order to build up a working group, it is important to consider the following issues:

- Learn about academic and professional management.
- Understand human relationships, challenges of separating personal and professional aspects.
- Provide funding and infrastructure to form a working group.
- Establish a work atmosphere based on respect and support for the individual projects of the group's researchers. Again, personal respect is the key.
- Protect students from personal issues that their supervisor has with other colleagues. His/her students should not inherit the supervisor's emotional problems.
- Ensure that the students have financial support and a good work environment.
- Avoid socially confusing situations. To provide an example, let us imagine a student who presents her research at an internal academic seminar, but there is an awkward atmosphere in the room. The student does not understand anything, and she believes that her study failed and that her classmates are not interested in the subject. The student does not know at the time that the problem is actually between her supervisor have with other senior peers. She is getting a bad reception for things

unrelated to her investigation. Unfortunately, in many cases, it takes a few years for the student to understand what the problem was at the time.

2 FINAL REMARKS. LEGACY

In retrospect, I wonder if the decision that I took 25 years ago to focus my scientific career in Mexico on developing a Space Weather observational network was correct? Now, I can answer myself that yes, it was right. I have had the privilege to lead an enthusiastic and professional working group. The group learned to do collaborative and multidisciplinary work. During these years, we built the confidence and self-esteem that comes with hands-on experience and solving problems. We are assembling a comprehensive observational infrastructure covering solar, interplanetary, geomagnetic, ionospheric, and cosmic rays. I feel deep respect and gratitude for all my LANCE colleagues. The data that we will be able to provide in a few years will be crucial to understanding the country's vulnerability toward Space Weather hazards. Keep in mind that global Space Weather parameters, characteristics, or indices may not replace Space Weather regional conditions measurements. These data sets are also important in terms of national sovereignty. This infrastructure and the historical records will provide huge opportunities to future generations for a deeper understanding of Solar impact on the Earth's environment.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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