PROCEEDINGS OF SCIENCE

INFLUENCE OF SOCIETY ON ASTRONOMICAL DISCOVERY

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I discuss the influence of society on astronomical discovery, concentrating on the last half century, during which astronomy evolved into a 'big science'. Astronomy is observationally driven. The observational facilities needed to make paradigm-changing discoveries have become so sophisticated and expensive that only funding on a global scale is sufficient to enable their construction and operation. Decisions to allocate such large amounts of public funding are inevitably political ones that need broad-based argumentation to justify them. I summarise the justification for modern astronomy and its benefits to society given in the new IAU strategic plan and suggest that participation in such activities is a cost-effective way for astronomers to stimulate funding for astronomical research. Finally, I discuss the influence of societal developments on the personality of astronomers, argue that these tend to stifle nonconformity and speculate about how the changes might affect future astronomical discoveries.

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1. INTRODUCTION

Since its beginning, astronomy has been moulded by its interaction with society. Early astronomy grew out of practical needs of primitive civilizations. As long as 35,000 years ago, the first known astronomers made calendars. Calendars played an important role in agriculture and hunting and making accurate calendars was also important for astrology. The origin of our profession owes more to the superstitious, to the religious and to magic than we often care to remember. The social needs for laws and hierarchies led to the growth of dogma and religion. Many of our ancient colleagues, pragmatic as ever, provided "technical support" for these bedrocks of ancient society through such practices as advanced astrological forecasting. By providing advice on such matters as the most auspicious dates for fighting wars, astronomers enhanced their prestige.

Throughout the great civilizations of the ancient world astronomy and astronomers prospered, but their work sometimes became divorced from providing practical benefits to society. Half a century ago J.D. Bernal described the state of spherical astronomy in Alexandria in words that could well be directed at a few branches of modern theoretical astrophysics [1] : "The scientific world was large enough to provide a small, appreciative and understanding elite for works of astronomy and mathematics so specialized that even the average educated citizen couldn't read them and at which the lower orders looked with awe mixed with suspicion." More ominously, Bernal wrote that "The whole scientific effort depended on an enlightened State. When that went, the edifice of learning largely collapsed."

Although navigation was an important practical driver for early astronomy it became a crucial motivation for doing astronomy for economic reasons in 15th century Europe. The great voyages of discovery were beginning and there was an increasing need to measure the position of the ships and their direction of motion. With their usual pragmatism, astronomers took advantage of the latest "sources of funding" to develop new instruments, which used the stars for ocean navigation. Later many large countries set up astronomical observatories as essential parts of their navies. In some cases these naval observatories have survived until the present time.

2. EMERGENCE OF MODERN ASTRONOMY AS A BIG SCIENCE

The modern astronomical revolution cannot be seen in isolation from the dramatic changes that shook western society at the beginning of the twentieth century. The cultural revolution in such activities as art and music was accompanied by the scientific revolution in physics and the technological revolution that led to such basic ingredients of modern life as electricity, cars and computers.

The two world wars played a significant role in continuing this metamorphosis of twentieth century society and in nourishing the rise of twentieth century astronomy. The Cold War and the quest for economic growth led to an explosive growth in defense spending and the rise of consumerism. These trends in turn drove the development of the new technologies that led to the fantastic astronomical discoveries that have emerged during the last half century. Without these technologies – electronics, sensitive radio optical and IR detectors, digital computers, atomic clocks and astronomical platforms in space – we would now have a very different view of the Universe.

Astronomy is an observationally driven science. Most of the paradigm-changing discoveries of modern astronomy were made by exploring new parameter-space in wavelength sensitivity or resolution. The research facilities needed to make substantial progress in astronomy have therefore become increasingly larger, sophisticated and more expensive. Large telescopes have become less and less affordable by individual countries – even rich ones. To fund many of the forefront astronomical facilities it has become essential to form regional consortia of countries or even global alliances, as is the case with ALMA. This trend is likely to increase in the future.

It is interesting to examine the reasons that led societies to spend relatively large amounts of funds on astronomical facilities in the recent past. Although the support of good science was sometimes part of this rationale, it is an illusion to believe that this was the only or even the major reason. During the last 50 years, chauvinism and the desire to enhance national prestige has often been an important motive. These factors were enhanced because the difference between astronomy and the "space race" became somewhat blurred in the eyes of the general public and politicians and superiority in space grew to be a "macho" desire of many countries. With the same pragmatism as that of our ancient colleagues, we astronomers exploited this situation for all it was worth.

"Minister! Ruritania has decided to develop a 10-m telescope. Surely we can't let these Ruritanians beat us. We must develop a 10.5m one to stay ahead. By the way Minister, as you will see from our well-argued science case that the new Urbanian telescope will be able to do things that the Ruritanian telescope can't. It will be a showcase for demonstrating the sophistication and innovation of Urbanian technology to the world"

Another route that astronomers have occasionally exploited to convince governments to fund astronomical facilities is is to "piggy back" on non-astronomical projects that appear to give more direct benefit to society. An example is the Low Frequency Array (LOFAR), a radio facility that is presently nearing completion in the Netherlands. LOFAR would probably not have been funded as a pure radio telescope. By providing sophisticated ICT technology to geophysicists and agricultural scientists and after making strategic alliances with industry, astronomers succeeded in obtaining funding for LOFAR as a "multi-sensor array". Applications of LOFAR that were crucial to its funding are to monitor the sub-structure of the earth under the Dutch gas fields and to enhance the high-tech infrastructure of north Netherlands, a relatively poor region of the country.

Paradoxically, the need to raise funding globally to cover the huge cost of next-generation facilities has seriously weakened such chauvinistic arguments for building astronomical facilities. Although there are indeed smart ways of doing significant "niche" astronomy relatively inexpensively, doing most paradigm-changing astronomical research will still need the construction of extremely expensive facilities to explore new parameter space. It will become increasingly difficult to raise funding for these, so it is essential to make a convincing case to policy makers why astronomy is useful to society in the modern world, both nationally and globally.

3. HOW ASTRONOMY CAN BENEFIT MODERN SOCIETY

How can we convince politicians and policy makers to approve funding for the future generation of large projects? A broad case for astronomy is made in the new IAU decadal plan for education, development and capacity building, "Astronomy for the developing world", [2], that will hopefully be endorsed at the closing business meeting of this General Assembly. The argu-

ments are illustrated in Figure 1, taken from the cover page of the plan. Astronomy is a unique and cost effective tool for furthering sustainable global development, because of its triple technological, scientific and cultural dimensions. Our new IAU plan shows how astronomy can contribute globally to education at the primary, secondary and tertiary levels and can enable less developed poorer countries to participate in cutting-edge scientific research. Astronomy can play a special role in stimulating science and technology at all levels.

• The Universe provides an inexpensive laboratory for studying extreme conditions that are inaccessible on Earth. Stars and galaxies are environments that have produced the chemical elements around us and formed organic molecules, the building blocks of life. During the last century astronomical studies have led to new discoveries in physics, chemistry and biology and to the creation of the new sciences of astrophysics, astrochemistry and astrobiology. Because of its mathematical basis, astronomy is also an excellent tool for teaching mathematics.

• Astronomy has been an important driver for the development of advanced technology, such as the most sensitive detectors of light and radio waves and the fastest computers. The need to study the faintest objects possible requires sophisticated electronics and extreme-precision adaptive optics as well as state of the art engineering. Astronomy has also played an important role in space technology that has opened the Universe for study throughout the whole electromagnetic spectrum. Modern optical and radio telescopes are among the most advanced machines ever built and are outstanding educational vehicles for becoming familiar with the latest complex technology.

Astronomy also contributes substantially to modern culture and is relevant to several topical issues of present-day society.

• Astronomy is history. Large telescopes operating throughout the electromagnetic spectrum are "time machines" that routinely provide pictures and other information about of the observable Universe close to its birth, 13.7 billion years ago. Unravelling the history of the Universe has been a crowning achievement of humankind during the last half century.

• One of the most important societal functions of modern astronomy is as a tool for education in the broadest sense. Because it is one of the most approachable of sciences that consistently fascinates young people, astronomy is an excellent vehicle for introducing science and technology to children. The accessibility of the sky, the beauty of cosmic objects and the immensity of the Universe are inspirational and provide a perspective that encourages internationalism and tolerance. The excitement of astronomy has stimulated large numbers of young people to choose a career in science and technology, thereby contributing to the "knowledge economy" of many countries.

A foresighted view of the importance of astronomy for developing nations is contained in a strategic document issued by the South African Ministry of Science and Technology in 1996 [3]: "It is important to maintain a basic science competence in 'flagship' sciences such as physics and astronomy for cultural reasons. Not to offer them would be to take a negative view of our future– the view that we are a second-class nation, chained forever to the treadmill of feeding and clothing ourselves".

In summary, because astronomy combines science and technology with inspiration and excitement, it can play a unique role in facilitating education and capacity building and in furthering sustainable development throughout the world.

The new IAU plan, based on these arguments the new IAU plan an ambitious flexible and credible blueprint for expanding astronomy development programs during the next decade. It contains

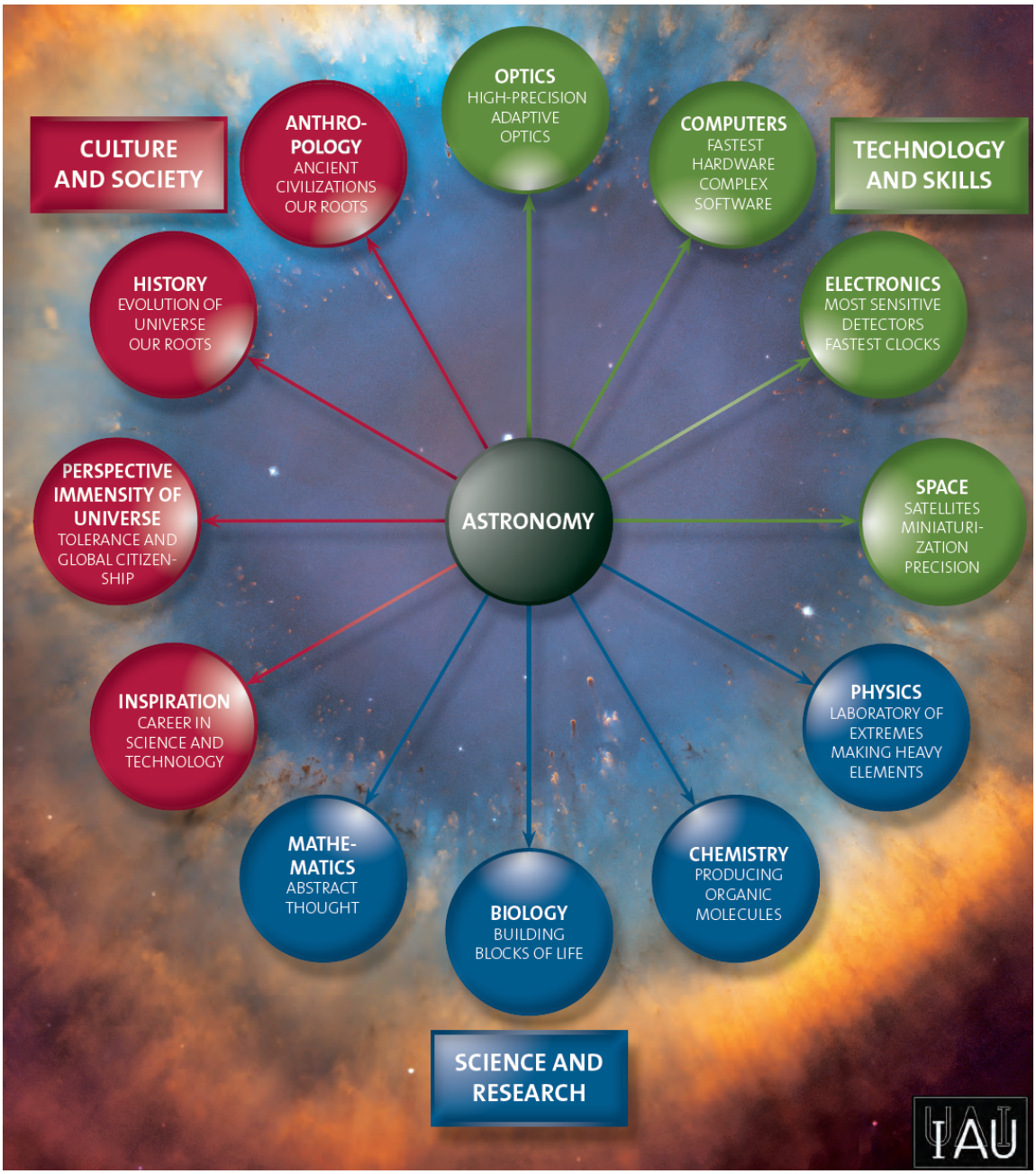

Figure 1: The front cover of "Astronomy for the developing world" the IAU Strategic Plan 2010 – 2020. This illustrates the uniqueness of astronomy as a tool for stimulating science, technology and culture, three characteristics of a developed country. Astronomy is a discipline that can be used for capacity building on a global scale.

a long term vision, achievable goals and a comprehensive new strategy for attaining these goals. The plan will be implemented with an effective and lean organisational structure subject to professional oversight. Involvement in such activities is a cost-effective way for astronomers to enhance funding for the large research facilities needed to make future astronomical discoveries.

4. CHANGING PERSONALITY OF ASTRONOMERS AND ITS EFFECT ON DISCOVERY?

In the preceding sections I have discussed how society and modern astronomical discovery are intimately linked. I shall conclude with some remarks about astronomers themselves. Do changes in the way astronomy is practised and the career structure imposed by modern society influence the personality of the typical professional astronomer? Could the changing profile of "the astronomer" have an effect on the likelihood and character of astronomical discoveries? I suggest that such an effect is highly probable.

Many of the most profound scientific discoveries were made by questioning nonconformists. In the words of the British physicist Jacob Bronowski, [4] "From Luther in 1517 to Spinoza grinding lenses, from Huguenot weavers and Quaker ironmasters to the Puritans founding Harvard, and from NewtonŠs religious heresies to the calculating universe of Eddington, the profound movements in history have begun by nonconforming men. Dissent is the native activity of the scientist, and it has got him into a good deal of trouble in the last years. But if that is cut off, what is left will not be a scientist".

Although the mainstream of scientific research is analytic and inductive, based on working within the existing conventional paradigms and assumptions, history shows that major breakthroughs are often made by scientists with imagination, who are not afraid to stick their necks out. Questioning basic assumptions, making observations or developing theories which colleagues might regard as crazy, taking risks in doing unconventional research are all important ingredients of paradigm-changing discoveries. Unfortunately, these qualities do not always result in cum laude degrees, or in a prolific publication record, nor are risky proposals usually honoured by peer review committees or the scientific establishment. Dissenters often have difficult and abrasive personalities.

There are at least three selection effects that act to selectively reduce the fraction of nonconformist astronomers.

• The evolution of astronomy into a big science means that "people qualities" such as networking, marketing and the ability to work well in teams are extremely important for survival. This effect operates at all levels of an astronomer's career, from recruitment to appointment and the granting of tenure. Nonconformists are more likely to be stubborn and difficult to deal with. When a department chairman is faced with 60 applications for a job, it is tempting to rule out the applicant who appears to have a difficult personality. When a tenure decision needs to be made, the socially inept staff member is at a disadvantage.

• The influence of economists and the emphasis of society on accountability, on publication records and on short-term productivity makes it increasingly likely that unconventional dissidents will fall by the wayside at an early stage of their career.

• The creative nonconformist is more likely to be alienated by the world of accountability, work packages and deliverables that is essential for the development and construction of modern large astronomical instruments. This effect inevitably tends to reduce the fraction of nonconformists in modern 'big–science' astronomy.

5. CONCLUSIONS

In this talk I have tried to demonstrate that the development of astronomy cannot be viewed in isolation from the development of society as a whole and that the influence of society on astronomy and astronomical discovery has increased considerably during the last century.

What conclusions can we draw to maximise the probability of future discoveries? I will mention three.

1. Future large astronomical facilities needed to make paradigm-changing discoveries will require funding on a global scale and the decision of society to fund such facilities will inevitably be based mainly on political grounds.

2. Devoting astronomical resources to global development and education, as outlined in the IAU plan will enhance the image of astronomy and thereby make politicians more receptive to allocating funds to astronomical research. Mobilizing astronomy in the service of global development is a cost-effective strategy for maximising future discoveries.

3. It is important to hire and promote creative scientists, even if they have difficult personalities. Although a department filled only with difficult people would probably be an unproductive nightmare, a "quota" of about 10% - 15% of creative difficult astronomers in each department and institute could substantially enhance the chances of future astronomical discoveries.

References

[1] J.D. Bernal, *Science in History* Watts Publishers, London, 1954.

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[4] J. Bronowski, J., *Science and Human Values*, Harper and Row Publishers, 1956.