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International Action

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Abstract. The roles of the International Astronomical Union, the other ICSU Unions, UNESCO and the UN are reviewed in order to assess the way forward to resolve a unique situation - the impact of civilisation on the observational procedures of a particular science - astronomy. Action to create a *modus vivendi* to allow the continuance of vigorous astronomical science within a vibrant technological society is suggested.

1. Introduction

Sections 1 and 2 of "Preparations for the Third United Nations Conference on the Exploration and Peaceful Uses of Outer space" (UN 1998) make reference to the power of astronomy to drive interest in space. That driving force today has suffered considerable dilution by the activities of humankind - also attested in Section 74 of the same document. The ground-based astronomer has to conduct observations of faint cosmic sources with instruments sitting on the ground at the bottom of the Earth's atmosphere. The Earth's atmosphere is, without doubt, the greatest single impediment to successful astronomical observations, given its rapidly varying state in both space and time. Astronomers have invested heavily - time, ingenuity, grit and money - to overcome the worst atmospheric excesses by moving observatories to the highest, driest, darkest or radio-quiet, remote sites this planet can offer. Leaving aside the fact that such paragons among sites often can be tectonically unstable, astronomy must now face activities of humankind which do much to magnify the undesirable consequences of observing from the bottom of the Earth's atmosphere, plus several more without parallel in nature.

The outlook for astronomy is clouded - metaphorically and literally! The technological virtuosity which has permitted the scientific triumphs of the last decades is also the greatest single threat to continued progress in astronomical science. Our widespread exploitation of science has led to a rising tide of electromagnetic noise which threatens to overpower and render faint cosmic signals undetectable. This tide is worst for radio astronomy but affects other wavelength bands as well. Heavy industry and transportation add to background atmospheric pollution and ground vibration. The release of greenhouse gases leads to higher temperatures, greater atmospheric turbulence and the risk of

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increasing cloudiness - already happening as a result of aircraft contrails. We contend with proposals for solar reflectors in space for earth illumination, artistic, celebratory or advertising purposes. We learn of solar radiation collection projects for major terrestrial power generation purposes which would have disastrous consequences for astronomy.

Yet the science of astronomy has been remarkably successful in understanding the nature of the Universe and the technological virtuosity of this century has created unparalleled, exciting prospects for the next. The progress of astronomy in this century has been dazzling - it could be even more dazzling in the next.

2. Why should Astronomy have Special Status?

Astronomy is one of the oldest sciences studied by *homo sapiens*. Its roots lie deep in prehistory. Since Galileo have we begun to get to grips with the essential physics of the Universe and the twentieth century has seen explosive progress in that understanding.

The value of astronomy has always lain in its practicality, whether for timekeeping, calendrical regulation, navigation, extending the horizons of laboratory physics or just extending horizons. Often regarded in our own age as being esoteric and "ivory tower", astronomy still has immensely practical value, not only in the above, traditional, areas, but also in obtaining detailed knowledge of the Sun's structure and evolution, solar-terrestrial relations and comparative planetology. The Sun cannot be understood in isolation from other stars in a Galactic context - indeed Section 77 of "Preparations... " (UN 1998) specially mentions the interstellar medium - a response which implies that proper understanding of the interstellar medium will contribute to the understanding of the solar system. Close the windows on the cosmos and our understanding of the Earth becomes incomplete. Where understanding lacks comprehensiveness, error of judgement is never far behind, as a study of astronomy through the ages so clearly demonstrates. Astronomy is an important science. It is one of very few sciences which must share its "laboratory" with the rest of humankind. Humans are making a very thorough mess of the astronomical "laboratory". If astronomy is to remain the creative, vigorous science it now is, it must have agreements in place which will allow astronomical science and a science-based society to flourish together. These agreements must be on an international basis, since the activities of particular groups that can have serious deleterious effects on astronomy are widely spread. We therefore seek a *modus vivendi* that is workable and allows all parties maximum freedom of action.

3. The Role of the International Astronomical Union

The International Astronomical Union (IAU) is a non-governmental organisation founded in 1919 under the auspices of the League of Nations to promote the development of astronomy internationally and to promote cooperation between astronomers irrespective of nationality, race, religion or ethnic background. In meeting those aims the IAU proved remarkably effective.

Table 1. Resolutions of the International Astronomical Union which relate to degradation of observing conditions

Year	Place	Trans B[1]	No.	Title	Source[2,3]
1961	Berkeley	XI	R1	Impact of space projects on optical and radio observations	EC
			R2	Project West Ford	EC
				Allocation of Radio Frequency Space for Astronomy	C40
1964	Hamburg	XII	R3	Support for Radio Frequency Allocation	C40
				Proposal: greater protection for OH at 1664, 1668 MHz	
			R5	Vapour Trails at Total Solar Eclipse	C12
1967	Prague	XIII			
1970	Brighton	XIV	R10	Impact of Use of Space on Astronomy	
1973	Sydney	XV			
1976	Grenoble	XVI	R8	Reduction of interference from bands neighbouring Astronomical Radio Frequency Band Adverse Environmental Impact on Astronomy	
1979	Montreal	XVII	(v)	Extension and Preservation of Astronomical Radio Frequency Bands	
1982	Patras	XVIII	R9	Protection of Radio Frequency Bands	
1985	Delhi	XIX	B3	CCIR (International Radio Consultative Committee) Actions	
			B6	Protection of Observatory Sites	
			B7	Danger of the Contamination of Space	
1988	Baltimore	XX	A2	Adverse Environmental Impacts on Astronomy	
			A5	Cooperation to save Hydroxyl Bands	
			A6	Sharing Hydroxyl Band with Land Mobile Services	
			A7	Revision of Frequency Bands for Astrophysically Significant Lines	
1991	Buenos Aires	XXI	A1	Sharing Hydroxyl Band with Land Mobile Services	EC
			A2	Revision of Frequency Bands for Astrophysically Significant Lines	EC
			A3	Preservation of Radio Frequencies for Radio Astronomy	EC
			A6	Working Group on the Prevention of Interplanetary Pollution	EC
1994	Hague	XXII	B3	Measurement and Mitigation of Adverse Environmental Impacts on Astronomy	C5
			B4	Prohibition of Satellite Systems having potentially adverse impacts on astronomy	C40
			B14	Sharing the Hydroxyl Band with Land Mobile Satellite Services	C40
			B15	Bands to be used for Radiocommunications in the lunar environment	C40/50
1997	Kyoto	XXIII	A1	Protection of the Night Sky	EC

[1] IAU Transaction B; [2]EC = Executive Committee; [3]C = Commission

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The impact of the requirements of society on astronomy was first perceived in radio astronomy. It was clear at a very early stage in the development of radio astronomy that the radio spectrum would have to be shared with other users and radio astronomers sought recognition from the International Telecommunication Union (ITU). Their success is a model to be followed but is the subject of another paper (Robinson) in this volume. However, let me recall simply that the three first IAU Resolutions on Adverse Impact, which appeared at the 11th General Assembly in Berkeley in 1961, concerned Radio Astronomy. These resolutions were: two from the Executive Committee on "the Impact of Space Projects on Optical and Radio Observations", "Project West Ford" and one from Commission 40 (Radio Astronomy) on "Allocation of Radio Frequency Space for Astronomy". Clearly we have been thinkng of adverse environmental impact for over 40 years. Table 1 lists the IAU Resolutions since 1961 which relate to the impact of society on astronomy - a significant number of these specifically concern radio astronomy.

The terminology "adverse environmental impact on astronomy" does not appear in IAU Resolutions until 1976 and from 1988 such resolutions have appeared in one form or another at every General Assembly, culminating in the Executive Committee Resolution of 1997 on the Protection of the Night Sky.

The IAU also has Commission 50, whose task is the Protection of Existing and Potential Observatory sites. This Commission has as its mandate, protection of observatory sites at any electromagnetic wavelength and at any site on Earth or in space. The Commission has played a considerable role in seeking protection of observing sites by way of local, regional or national agreements, by giving support to those planning new observatories. C50 (IAU 1978) jointly with CIE (Commission Internationale de l'Eclairage) published a Report and Recommendations on Adverse Environmental Impact on Astronomy and the Protection of Observatory Sites which contains much information of value today. This Report was republished in *The Vanishing Universe* (McNally 1994).

The IAU has sought to maintain awareness of all types of adverse environmental impact that can affect astronomy. Not only are we dealing with electromagnetic pollution at all wavelengths, but we must consider sources of ground vibration, heat input to the atmosphere, changes in weather patterns (both global and local), accumulation of chemical absorbers in the atmosphere, balloons (Sky Stations) for communications relays, laser communications, the effects of satellites trailing astronomical fields under observation, terrestrial pollution of the solar system, and the effects of solar reflectors and other sources of "bright" lighting in space. It is a list which grows with time and the deleterious effect of each of these problems grows with time. Commission 50 has organised two meetings on this topic - IAU Colloquium 112 in 1988 (Crawford 1991) and IAU Symposium 196 in 1999 (the present volume).

IAU Colloquium 112 (Crawford 1991) was a defining marker of astronomical concern. It reviewed electromagnetic pollution and space debris issues. It defines the situation as it existed prior to 1988 - a situation which has, overall, got worse and encompasses more adverse impacts.

There have been other meetings since, e.g., the NATO-sponsored study *The Protection of Astronomical and Geophysical Sites* (Kovalevsky 1992) and the Proceedings of the IAU Joint Discussion in 1997, on *Preserving the Astronomi-*

cal Windows (Isobe and Hirayama 1998). The IAU has put considerable effort into examination of the problems posed by the impact of modern technological civilisation and astronomy. We are very conscious of what these problems are. But there is still a great deal to be done to convince not just the public generally, but also our colleagues, of the seriousness of the problem that exists. The public is unaware of the seriousness of the problem, whereas our colleagues harbour an unreasonable optimism that by some chance the problem will go away. Because the threat to the observational work of the major international observatories is not yet too apparent, the fate of the small observatories closer to civilisation is not a major issue to some. That is a short-sighted view, firstly since much excellent, essential work can only be carried out at small observatories, such is the demand for telescope time at the major international observatories, and secondly because it is only a matter of time before these major, more remote observatories will also be seriously impacted. Simple action can produce worthwhile amelioration, as you have heard, and will hear, many times in this Symposium. Even in radio astronomy - the most seriously affected area of astronomy, as you hear from Brian Robinson - the burden of maintaining reserved frequency space is carried by very few people and the efforts of national and regional bodies like CORF and CRAF, and international bodies such as IUCAF, are the reason why radio astronomy can be conducted at all today. They are to be highly praised for their example and for their dedication.

The IAU can offer support (e.g. IAU/CIE Document 1978) to those attempting to negotiate on behalf of specific types of observation. There is international backing for efforts to obtain local agreements as well as a wealth of experience of such negotiations. It must be recognised that the existence of local agreement, e.g. on outdoor lighting, has consequences for local people which can be restrictive. We astronomers should not forget that our dark skies or low-noise radio observatory comes at a cost to the local neighbourhood. Yet it is remarkable how much goodwill exists and how much local pride is generated by hosting a major observatory.

The threats to astronomy are very far-reaching - particularly those from space. Ground-based threats can often be minimized by retreat or local agreement. Retreat can bring advantages - such as high, dry sites in otherwise inhospitable places. However, there is now no opportunity for further retreat. There is no escape from assaults from space. Signals from space reach the most remote mountain-top observatory as they do the most populous of cities. Bright objects in space cannot avoid passing over the remotest observatory. Radio signals from space are a major threat to the detection of weak cosmic signals by radio telescopes. Bilateral agreements on space activities are of little use, as many of such enterprises are multinational in character, embracing highly diverse groups ranging from governments and multinational companies to small businesses. Therefore there must be international recognition of the problems faced by astronomy. I shall return to this in Section 5.

4. International Partners

It is important to realise that astronomy does not stand alone on the issue of adverse environmental impact. Other sciences also suffer from the activities of a technological civilisation.

(i) Geophysics: Electromagnetic pollution is a problem for geophysics in the study of air-glow, aurora and other geophysical phenomena and indeed the acceptable limit for increase in background levels of illumination for such studies would be less than the 10% increase often quoted for astronomy. The same concern is shared by those studying the zodiacal light and gegenschein. The Earth's magnetic field is a major area of research. However, major electrification schemes give rise to changes in local magnetic fields of the order of two nanotesla at 10 km distance - a variation an order of magnitude greater than the sensitivity of commonly used magnetometers. Ground vibration is as significant an issue for seismometry studies as for astrometric observations. Vibration from trucks, trains, etc. can remain significant at distances of over 3 km. Geophysics is also concerned about the chemistry of the atmosphere and the effect of industrially produced effluents on the balance of the natural atmospheric chemistry.

The geophysics community bring out a further concern - vandalism at automatic recording stations. With a movement towards more robotic telescopes, this is likely to become a greater concern for the astronomy. The IAU therefore cooperates with the IUGG (International Union of Geodesy and Geophysics) and with SCOPE (Standing Committee on the Problems of the Environment) to exchange information and to maintain awareness of common hazards as they arise. Currently the overlap of interest of the IAU with SCOPE is not great, but the contact is valued in maintaining a link with other environmental considerations.

(ii) Meteorology: Astronomers must observe through the Earth's atmosphere - the preserve of meteorologists. Both groups have parallel but not identical interests in changes in atmospheric extinction, the consequences of global warming and changes in global distribution of cloud. Recently, atmospheric scientists have communicated their concerns over space debris, which degrades the quality of observations obtained by northward-looking polar atmospheric radars. The IAU has representation with the WMO (World Meteorological Organisation), but this is an area where more frequent exchanges and better contacts are needed, for example with regard to the meteorological downward-looking radars which are of concern for radio astronomy.

(iii) COSPAR (Committee on Space Research): COSPAR maintains a Panel, PEDAS (Potentially Environmentally Detrimental Activities in Space), to alert COSPAR to proposed space ventures which may prove damaging to the environment. PEDAS and the IAU share the key concerns of increasing levels of radio noise and debris damage to orbiting observatories.

(iv) UNESCO (United Nations Educational, Cultural and Scientific Organization): UNESCO has been a helpful partner in advertising the concerns of the astronomical community regarding adverse environmental impact. UNESCO is the "parent" of the ICSU family of Scientific Unions and Committees. UNESCO supported the efforts of the IAU in mounting an exposition at the UNESCO headquarters in Paris, to advertise the threats to continued high-quality astronomical observation. This exposition resulted in the publication of a book (McNally 1994) which set out in simple terms the range and severity of the

threats facing astronomy. The astronomical community is also very grateful to UNESCO for taking the important, defining decision of turning down an opportunity to mark its first 50 years with a commemorative space project, the "Star of Tolerance".

(v) CIE: The collaboration which has been developed over the years between astronomers and lighting engineers has proved extremely successful, indeed it is another role model. The modern road lighting schemes are a daily reminder that well-considered lighting design gives good visibility and low light-spill.

(vi) UN: The IAU has developed links with the UN COPUOS Scientific and technical Sub-Committee, resulting in an invitation to assume Observer Status. This recognition is highly appreciated by the IAU. One outcome is that this symposium is being held at the UN. The opportunity to have a direct line of communication for the presentation of the serious concerns of the international astronomical community to the UN is of immense value.

The IAU wishes to cooperate and collaborate with all sciences adversely affected by the activities of society, e.g with the biological sciences on the ecological impacts of light pollution. The astronomical community is not alone and must explore with sister sciences the range of measures that urgently need to be taken in order to protect the integrity of observational and other field work. To this end, at first under ICSU auspices and now under IAU auspices, there is a small Working Group which keeps the collective threat under review.

5. International Action

Adverse environmental impact is not the preserve of astronomy alone. Other sciences also suffer. The problems are now so widespread, as pointed out in Section 3, that it is necessary to ask for international action to protect the integrity of the sciences affected.

It is clear that the sciences particularly affected have a close connection with the Earth's environment - astronomy, meteorology and geophysics. It is perhaps novel to consider astronomy in the context of the Earth's environment, except when it is recalled that it is astronomical considerations which are the fundamental determinants of the Earth's environment and that ground-based astronomy is conducted from the bottom of the Earth's atmosphere. Astronomy is irretrievably involved with the Earth's environment. Indeed, because astronomy investigates very faint sources, it is particularly seriously affected by tiny environmental changes.

It was pointed out above that the major sources of adverse environmental impact on astronomy are international. In their severest forms these impacts come from the exploitation of space. Light pollution can be mitigated, terrestrially-generated radio noise can similarly be controlled for specific sites. However, because of the intrinsic nature of space operations, there is no way to escape man-made noise from space. Equally, there are no rational grounds to argue that the science of astronomy should be severely harmed or even nullified in order that the exploitation of space can carry on without paying due regard to consequences for others. The science of astronomy must seek protection of its interests, that is, its sustained capability to carry out significant astronomical observations of faint cosmic sources over a wide range of frequency bands.

Since the exploitation of space is carried out on a multinational basis between cooperating governments, agencies and multinational companies, any protection for astronomy must be agreed at an international level. In this Symposium, very many different environmental impacts on astronomy have been, and will be, laid out. Any single environmental impact can be discussed in isolation, but in the last analysis it is the sum total of environmental impacts that must be addressed.

Because astronomy, unlike most other sciences, is not in sole control of its "laboratory", including the ground-based environment, the actions of others will always affect the quality of that "laboratory". We therefore seek ways in which a *modus vivendi* can be agreed so that astronomy and beneficial exploitation of space can coexist. I urge the UN COPUOS to take up consideration of such protection at their earliest opportunity - otherwise the future for astronomy will be bleak indeed.

6. Conclusion

The science of astronomy is now threatened on so many fronts, with particularly serious consequences for radio astronomy, that international protection must be urgently sought. The greatest single source of threat is the exploitation of space. However, it is the totality of the threat that must be considered when, for what is probably the first time, a science has requested special regulation to allow it to continue with its essential observations. The situation is potentially so serious that it is all too easy to foresee doomsday scenarios. However, we believe that it is important to the body of all scientific activity that a vigorous astronomical science is maintained, and that ways will be found to establish a *modus vivendi* in which astronomical science can continue to flourish in parallel with a technologically vibrant society.

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