JD5 "PRESERVING THE ASTRONOMICAL WINDOWS"

Supporting Division: X(Radio astronomy)
Supporting Commissions: 40(Radio astronomy), 50(Protection of existing and potential observatory sites)
Co-supporting Commissions: 8(Positional astronomy), 21(Light at the night sky), 46(Teaching of astronomy), 51(Bioastronomy:search for extraterrestrial sites)
SOC members: N. Brouillet(France), B. Hidayat(Indonesia), Jingyao Hu(China), S. Isobe (Chairperson, Japan), Ch. Leinert(Germany), K. Mattila(Finland), D. McNally(UK), WJ. Percy
(Canada), W. Wamsteker(Spain), and J. Whiteoak(Australia)

Held on August 21 and 22, 1997, during the XIIIrd General Assembly in Kyoto.

In these decades astronomy has been developing very much because observations in optical, radio, and the other wavelength domains as well as neutrino, cosmic ray, and in-situ observations have been extensively carried out collaborating with theoretical works. However, it is also true that astronomical observational conditions have become worse and worse during these same period. Astronomical observers are suffering light pollution, radio interference, and space debris. IAU had realized these problems and set up a commission to deal these matter in 1978 : that is the Commission 50 "Protection and identification of existing and potential observational site. The Commission organized the IAU Colloquium No. 112" (D. Crowford 1991) in Washington D. C, USA, from 13 to 16 August 1988, and extensively discussed the matters. Some number of astronomers worked so hard to reduce the problems by contacting and collaborating with the other organizations such as CIE, COSPAR, URSI, ITU, IAD, and UNESCO, UN. One of these activities was a joint meeting of UNESCO, ICSU, IAU, and CSR held in Paris from June 30 to July 2 1992, that is "Adverse Environmental Impact on Astronomy" (D. McNally 1994). However, since most of the observational astronomers have been busy to work out their own observations, the problems have still become worse.

The JD5 is a meeting inside the IAU. The main purpose of this JD is to know present situations of different interferences, to find ways to reduce the problems, and most importantly to make many IAU members realize the problems. Fortunately, we could have a talk by L. Woltjer, the President of the IAU, relating investments of astronomy and those loss by the problems dealed in this JD5. This is an important point which we, astronomers, should always think about Astronomy uses some billion US dollars per year and our loss becomes some fractions of this value.

We had 23 talks including the President, 9 paster papers, and nearly 200 audiences who attended at least some session(s). Therefore, the JD5 was successful with many discussions.

To approach public people, different organizations, different governments, and UN, on the problems, there are many ways, but it is inevitably necessary for us, astronomers, to do much efforts. Astronomers actively working on the problems gave reports during the JD5, and the followings are short summaries of their talks. Those full papers describing in much detail will be published in the other book (Isobe and Hirayama 1998). It is highly expected that all the IAU members start to consider the problems which may kill astronomical observations.

Syuzo Isobe (Chairman of JD5)

1. ADVERSE ENVIRONMENTAL IMPACT ON ASTRONOMY

D. McNally (University of London Observatory)

J. Andersen (ed.), Highlights of Astronomy, Volume 11A, 205–218.

This paper sets out to urge the quantification of adverse environmental impact on astronomy (AEI). Up to the present AEI has been treated anecdotally. This is not a criticism - the demonstrations have been compelling, particularly so in the case of light pollution. However, we must now move from demonstration to effective action. That effective action will impact the legitimate activities of others. Therefore astronomy will have to present evidence capable of convincing not just those sympathetic to the astronomical community, but the community in general that astronomy has a legitimate grievance and that the redress being sought will be effective in improving astronomical observing condition.

In order to be convincing we must quantify. We must be able to state, for example, what background levels of light pollution are, what the normal range of the level is and how the level is changing from year to year. All claimed adverse impact should have some measure to express the real nature of the impact. Only when such measures are in place can we argue for legal protection.

The problems to be faced in quantification must not be minimized. The problems are considerable and each adverse impact has its own unique set. Some of the problems are outlined in the paper. Unfortunately time is not on our side. Every year sees a rebirth of the concept of advertising from space in one form or another. Sooner or later, unless we are supremely vigilant, a proposal will be accepted and the consequences will be disastrous for our science. Hence the thrust of the EC Resolution before this General Assembly.

There is now great investment in astronomy as a science. That investment has produced some of the most exciting astronomy in all history. One only has to think of the spectacular discoveries of the HST, the advance in basic astrometric data represented by HIPPARCOS, and the unparalleled spectroscopic data base from IUE. We are currently looking forward to the fruits of the 10 m generation optical telescopes and sustained adventures in radio astronomy. Yet that tantalisingly brilliant future is at risk.

Unfortunately the interests of astronomy are now in conflict with other human activities. Astronomy has retreated to its mountains, deserts and into space. It can no longer retreat-there is nowhere left to go. The other competing interests are well heeled profitable and will claim enormous benefits for society. Some of the benefits are real but not all. We as astronomers will have to come to terms with the rest of society- but by the same token, the rest of society will have to come to terms with us - if astronomy is to survive as a major science. It would be a great disaster for the whole of science were the science of astronomy to be curtailed by the pollution produced terrestrially. Loss of investment would be disaster, loss of cosmic perspective would be a catastrophe.

2. IMPACT ON RADIO ASTRONOMY

M. Morimoto (Space Science Course, Kagoshima University)

The radio sky has continuously supplied "exotic objects" to astronomy, such as quasars, pulsars etc. After a while these objects proved to be important constituents of the Universe and provided a new look of the Universe.

Cosmic Background Radiation is the remnant of the blackbody radiation of Universe when it was cooled to about 3000k. Density of quasars is higher in the distant part of the Universe and proves the Universe was more crowded in the early stage.

Spectral line emission from molecules formed in the interstellar gas clouds shows processes of star formation in the Galaxy and galaxies.

Technology in radio telescope in also continuously in a rapid progress. Recent success of HALUCA satellite and VSOP has opened a new era of high resolution radio imaging through space VLBI. Accuracy of source position measurements is approaching 1 microarcsec as level and trigonometry will soon cover whole Galaxy and beyond.

These are only a small portion of achievements of radio astronomy, but prove that it continues to contribute important parts of the human knowledge of the Universe.

On the other hand, this exciting field of science is critically endangered by the more and more intense usage of radio spectrum for communication and other purposes.

Frequencies below ~ 300 MHz (m-waves and longer)

Low frequency radio emission represents low density plasmas in Universe, which is difficult to observe by other means. Examples are outer corona of the sun, envelope of the Galaxy and galaxies etc. Developments in array technology, image processing etc has enabled more sophisticated observations especially with higher angular resolution.

However, the situation may NOT allow the human being to enjoy this improvement fully. Protected bands are very narrow here, because this is the most crowded frequency band and allocation is given in terms of very small widths.

High resolution observations will become possible by use of arrays of space baselines. A different set of protection criteria will become necessary.

300–30000 MHz (dm to cm waves)

This is the band where most of the important discoveries were done and developments in new technology are in progress, but on the other hand, the most intensively used band by communications and other purposes. New demands such as satellite systems for personal pocket phones etc are rapidly growing but there is no resources of unused bands.

Situation will become more serious as more and more new demands will require space to earth transmission with relatively high power and to cover essentially whole surface to the earth. If some substantial measure NOT taken, human eyes in this important spectrum will be black out.

Above 30 GHz (mm and sub-mm waves)

Molecules in the interstellar clouds display a very large number of spectral lines mainly through *rotational transition. It provides an unique possibility of direct observations of cool* gas phase in Universe. Interference situation is not YET serious.

The band is not used very actively because of the cost and technical demands will be pointed to this area very soon.

Frequency as the treasure of Nature

Originally, communications lived in a small area, perhaps below 50MHz. After the 2nd World War, the "big march" to the higher frequencies started and conquered the whole microwave region, which was, although sparsely, already inhabited by radio astronomy. Conquers allowed the original inhabitant to survive within narrow protected areas.

Frequency is like land. It is finite and easy to use up. It belongs to Nature. It is NOT owned by anyone.

Developments in the technology is at present encourage demands to USE the new frequency bands rather than protecting it, or in other words, Nature is protected only be the technical difficulties to use the band rather than the human wisdom.

Conclusion

We are about to lose the radio sky, which has continuously provided fascinations to the human being. Just like in other frontiers of the conservation of Nature, a use of the human wisdom to protect Nature rather than destroying is only the solution out or it.

3. LIGHT POLLUTION: ITS DAMAGE TO EDUCATION AND CULTURE

J. R. Percy (Erindale Campus, University of Toronto)

One could argue that light pollution has no impact on education or culture, because so few people care about real science. Perhaps people prefer bright lights, and "space art". The word *education*, however, comes from the Latin word *to lead*, and *culture* obviously refers to cultivation. It is our responsibility to educate the public in astronomy, and in the issues related to light pollution and related topics, and to cultive their appreciation of the night sky, and the universe.

Astronomy is important to education and culture because of its deep historical roots, its practical and philosophical applications, its aesthetic and emotional appeal (the beauty of the universe, and the sense of shared exploration and discovery), and its message about our place in time and space, and our cosmic roots and environment. In the classroom, it demonstrates the observational approach to the scientific method, and is a wonderful tool for teaching concepts of light, and gravity. It attracts young people to science and technology, and promotes public interest in science. Like all science, however, it is best taught through inquiry—simple, "hands-on" (or "eyes-on") activities. This is difficult in light-polluted skies.

Ironically, light pollution provides interesting opportunities for student projects, because it has scientific, technological, and societal aspects. Several groups have developed such projects, including co-operative, Internet-based projects in which students measure light pollution with simple devices,

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and then send their measurements to a central database. Students can also study light sources in their neighbourhood, using simple transmission diffraction gratings—a good cloudy-night activity!

Light pollution also hinders the recruitment, training, and work of amateur (volunteer) astronomers. Amateurs make important contributions to astronomy research and education. Amateurs in many parts of the world—including Japan—have carried out important studies of light pollution, thanks to their skill and motivation. They are our allies—"grass-roots" voices for the preservation of the astronomical environment.

The issue of space debris is somewhat more difficult, since we have no control in the matter; most people, however, can relate to the problem, because of widespread media reporting of space activities. The issue of the pollution of the electromagnetic spectrum is even more difficult, because people have no direct experience with it, and they somehow feel that scientists can overcome any technological problem of this kind. Public education is an essential part of any solution.

What can we do about light pollution? We cannot just replace the real sky by the planetarium sky, or the computer screen—useful as these may be. We cannot expect people to travel to dark sites, even though the rich and motivated can do so. We cannot do all astronomy from space, even though this is a popular misconception. We must promote astronomy education and culture, and encourage our colleagues and students to do the same. We must educate ourselves about the preservation of the astronomical environment, and "spread the word". We must work with partners: teachers, amateur astronomers, lighting engineers, and the media, to achieve these goals. We must support organizations such as IAU Commission 50, and the International Dark-Sky Association. We must promote an appreciation of the night sky by making skygazing a part of our courses, and other activities. Few people who have seen a dark sky are unmoved.

4. NATURAL OPTICAL SKY BACKGROUND

Ch. Leinert[a] and **K. Mattila**[b] ([a] Max-Planck-Institut für Astronomie, Heidelberg, Germany; [b] University of Helsinki Observatory, Finland)

4.1. INTRODUCTION

Knowledge of the natural dark night sky brightness is required if one wants to set meaningful limits to the disturbance by artificial illumination. Knowledge of the behaviour of the natural dark night sky brightness is also required if one wants to monitor the sky for existing or changing light pollution. Therefore, before coming to quantitative results of night sky brightness measurements, we give an overview on the different components of night sky brightness and their different behaviour. From this, recommendations will result for the planning of future sky brightness monitoring programmes, as they are requested in the first of the proposed IAU resolutions to result from this joint discussion.

4.2. BRIGHTNESS OF THE COMPONENTS OF THE NIGHT SKY

The light of the night sky comes from several "layers" at vastly different distances. Neglecting the small contribution from extragalactic background light and the diffuse galactic light, which approximately can be taken as a 20% addition to the light of the stars, the main contributors to the night sky brightness are—the integrated starlight due to our own galaxy (15–200 S_{10} [1 S_{10} unit = one 10^{th} magnitude star per square degree = $2.17 \cdot 10^{-8}$ W/m^2 sr μm at B.]), —the zodiacal light, due to scattering of solar radiation on interplanetary dust (30–100 S_{10}), airglow emission from the high atmospheric layers (50–180 S_{10}), and scattering of these components in the troposphere. The light pollution, of course, results from troposheric backscattering. Tropospheric scattering contains two components: Rayleigh scattering, with almost isotropic distribution of scattered brightness, and Mie scattering by aerosols, preferentially scattering into the forward direction ± 30 °. These two components are present in the artificial sky illumination as well, i.e. the observable sky brightening towards a city is not the whole story. There is an almost isotropic Rayleigh component as well!

4.3. TEMPORAL VARIATIONS

Most of the variations are due to Airglow, sometimes by a gradual decrease during the night, but fluctuations and continuous brightness increases occur as well. Differences from night to night may be substantial (20–50%), and this is a most significant effect to be considered when measuring changes in light pollution!. The variations with solar cycle are of similar size (≈50%) and correlated to the solar 10.7 cm flux.

There are indirect temporal variations caused by the passage of Milky Way and the zodiacal light, which may introduce spurious variations in measurements taken at different hours or days. Some change in scattered light intensity will also occur by the diurnal motion of these extended light sources.

There is a slight annual variation of zodiacal light, by about ± 10% at high ecliptic latitudes, due to the Earth's orbital motion within the interplanetary dust cloud.

4.4. BRIGHTNESS OF THE NIGHT SKY

Measurements of dark night sky brightness at different observatories lead to best values of typically 22 mag/square arcsec in V, 23 mag/square arcsec (≈ 100 S_{10}) in B. The spectrum of the night sky is dominated by strong airglow lines e.g. at 557.7 nm [OI], 589 nm [NaI], 630 nm [OI] and OH emission at longer wavelengths. Comparatively dark spectral bands are from 380 nm to 400 nm, 450 nm to 520 nm, 640 nm to 710 nm, and around 820 nm. If a choice has to be made, try to protect these bands!

4.5. RECOMMENDATIONS FOR LIGHT POLLUTION MEASUREMENTS

Therefore, if one wants to avoid mixing up natural changes with man-made increases in monitoring of light pollution, the following measures are recommended:

- Perform measurements at preselected, known positions on the sky, document all relevant coordinates, avoid stars or correct for them.
- Measurements should cover a sufficiently long interval (several hours per night/ several nights) to be free of "random" airglow variations within a night and from night to night.
- Measurements should cover a substantial fraction of the solar 11-year cycle or, at least, take the effect of solar activity into account when comparing measurements from different years.

5. FIELD SURVEY OF OUTDOOR LIGHTING IN JAPAN

K. Narisada, K. Kawakami

The Illuminating Engineering Institute of Japan conducted a field survey concerning the outdoor lighting in 1995, in various areas of the country. The aim of the survey was to find which types of luminaires in existing lighting installations are wasting the greatest amount of upward flux into the sky. The survey was conducted in six of the seven zones, proposed in an earlier draft of the guide of the CIE, i.e. E1, E2a, E3a, E3b, E4a and E4b. On the basis of the results of the survey, the proportion of the upward flux per 100 hectares was compared separately for eight types of luminaires, such as the luminaires for traffic roads, residential areas, decorative (shopping) streets, projectors, luminous signs, etc. As a result, it was found that the major sources of the upward flux were the luminaires for decorative streets and luminous signs and to be improved their photometric characteristics.

6. BILATERAL AGREEMENTS ON LIMITS TO OUTDOOR LIGHTING; THE NEW CIE RECOMMENDATIONS, THEIR ORIGIN AND IMPLICATIONS

D. A. Schreuder

Summary

Sky glow presents itself as a background luminance over the sky, against which the astronomical objects are to be observed. The interference of astronomical observations is caused by the resulting reduction in luminance contrast. The glow is caused by non-directional scatter of light by particles in space and in the atmosphere. Part of the light, and part of the particles are natural, and part is man-made. The '(natural) background radiation' is defined as the radiation (luminance) resulting from the scatter of natural light by natural particles. For earth-bound observatories, the background luminance is the limit for sky glow. It is customary to express the sky glow (from man-made sources) as a percentage of the natural background luminance.

The main sources of stray light that may interfere with astronomical observations are:
. lighting of industrial sites, airports and building sites;
. road and street lighting;
. advertising signs
. floodlighting of buildings, discos and monuments
. lighting of billboards
. lighting of greenhouses
. lighting of sports facilities
. area lighting of sales areas, parking lots, farm yards, railroad yards etc.

The Commission Internationale de l'Eclairage CIE set up 'Guidelines for minimizing sky glow; A CIE Technical Report'—presently in print. Most recommendations are expressed in values of the Upward Light Output Ratio—installed (ULORinst). The recommendations are based on three principles:

* the requirements for upward light emission are related to the activities in the 'zone' under consideration ('zoning');

* the requirements for upward light emission are most stringent in the 'night'; they may be relaxed in the 'evening' ('curfew');

* the lighting requirements in nearby zones must be taken into account (distance relations).

The future plans for the CIE Technical Committee CIE TC 4-21—in close collaboration with IAU Commission 50—include:

. preparing Draft ISO-Standards for measuring methods and for limiting values of sky glow

. preparing a draft manual on the theory and practice of road lighting for astronomers and for highway authorities.

. collect routine sky brightness measurements from various observatories

. contribute to the education of astronomy and the role of lighting there-in.

7. U.S PERSPECTIVE FOR INTERFERENCE TO RADIO ASTRONOMY

T. E. Gergely (Division of Astronomical Sciences, National Science Foundation)

During the last decade a number of new radio telescopes were built, and several are currently in various construction, design or planning stages. These instruments represent a substantial scientific investment, and radio astronomy continues to contribute many new ideas and results to astronomy. At the same time, the regulatory environment related to the radio spectrum has undergone considerable liberalization in the USA, as well as internationally. In the USA responsibility for spectrum utilization is shared by the National Telecommunication and Information Administration (NTIA), that oversees Government uses, and the Federal Communication Commission (FCC), that looks out for private sector spectrum needs. US spectrum management principles, as stated by the FCC, include the fostering of competition, flexibility of spectrum use, licensing and spectrum fee policies geared towards supporting the value of the spectrum and looking out for both the global market context and the public interest. Regulatory support of radio astronomy under the last item on this list is certainly not very high among FCC priorities. Similar situation prevails at the International Telecommunication Union (ITU), which regulates the uses of the radio spectrum internationally.

The last decade also has seen an expansion of satellite based radio services. Satellite technologies with substantial spectrum demands include the mobile satellite services, digital audio broadcasting, direct-to-home broadcasting and advanced fixed and fixed satellite services. This last name is a euphemism for satellite systems currently planned for distributing Internet and related material and other high data rate applications. The large expansion of satellite services, simultaneously with the relaxation of regulations, threatens radio astronomy. Considerable spectrum has been reallocated to satellite downlinks, and unavoidably (and sometimes avoidably) these are found next or near enough to radio astronomy bands so that spurious and/or out-of-band emissions spill over, and make astronomical observations difficult or impossible. The increasing spectrum congestion at cm and dm wavelengths, the wide bandwidths needed for Internet applications, and the availability of mm-wave technology are beginning to be felt in the mm and sub-mm regions of the spectrum, which astronomers considered their exclusive domain until recently, regardless of the allocation table.

Solutions to these problems will not be easy. Astronomers will need to educate the general public, as well as the regulatory authorities. In doing so, they must keep in mind that many new and satellite based services are extremely popular. The astronomy community will also have to get more involved in the various regulatory fora, and establish good contacts with industry. To do so will require that more human as well as financial resources be dedicated to spectrum management activities.

8. JAPANESE PERSPECTIVE FOR INTERFERENCE TO RADIO ASTRONOMY

K. Kawaguchi (NRAO, National Astronomical Observatory)

Interference to radio astronomical observations becomes serious, especially in relatively low frequency regions. Since general discussions on interference are given in other papers of this conference, the present paper describes some examples of interference detected in recent astronomical observations and future perspective.

I. Spurious in fringe detection between Kashima and VSOP in 1600 MHz region Recently, ISAS (Institute of Space and Aeronautics) launched a spacecraft HALCA with 8-m radio telescope for very long baseline interferometer. The first fringe test was carried out on 1997 May 7 for VSOP (VLBI Space Observatory Program) using the Usuda 64-m and Kashima 34-m ground radio telescopes and HALCA space telescope. In the test, the Kashima telescope received extended spurious noises at 1642.5 MHz, which made it difficult to detect fringes between HALCA and Kashima. Then the observation frequency was shifted to 1670–1686 MHz to avoid spurious in Kashima, and fringes were successfully detected between Kashima and HALCA. The band is protected as radio-astronomical band, but it is noted that such strong spurious are present for interference the astronomical observations.

II. Spurious in Taurus Molecular Cloud-1 observations with Nobeyama 45-m telescope The telescope site Nobeyama was chosen by considering to be free from radio interference. The site is surrounded with mountains and sparsely populated. However, it is found that recent development of various communication systems give large interference to radio observations below 30 GHz region. Especially when we observe quiet, cold dark astronomical source like TMC-1, where spectral line width are narrow as 0.6 km sec^{-1} (60 kHz at 30 GHz), it becomes very difficult to discriminate real lines from artificial spurious emission, even if a position switching method is employed for astronomical objects.

III. 95-GHz cloud profiling radar CRL (Communication Research Laboratory, Japan) and NASDA (National Space Development Agency of Japan) have project of a cloud profiling radar system from satellite for investigation of global warming which can be emotive issues. The radar system will use 3 mm radiation by considering scattering effect and established technology levels.

The frequency is also very important for radio astronomical observations. The following interference will occur,

(1) Main lobe—main lobe coupling
In the case of the Nobeyama 45-m telescope, the received power from the radar is estimated to be about 1 W by considering the sizes of radar beam and telescope. Since the destruction power for SIS (Superconductor-Insulator-Superconductor) junction is estimated about 10 mW, the radar power is two order of magnitude larger than the destruction power.

(2) Main lobe (telescope)—side lobe (radar) coupling
This is the case that a telescope sees a radar side lobe. Usually an SIS mixer receiver is working with a local power of 10^{-9} W, and higher local power gives a change in bias point and results in increase of noise temperature.

(3) Side lobe—side lobe coupling
This is the case that a telescope receives a power less than receiver saturation level, but the radar radiation is observed as a spurious line at the exact radar frequency. The telescope receives more power than harmful interference level (Pr = −203 dBW at 90 GHz region), for a shorter distance than 1080 km. If the satellite radar system wants to use the 95 GHz band, the band must be allocated to active sensing from satellite. From astronomical points of view, we are worry about such thing that many active services use the 95 GHz region after the allocation. The 95 GHz region is also not allocated for radioastronomical bands, but the effects (1) and (2) from radar make it difficult to observe in radio astronomical bands of 3 mm region. We must make efforts to reallocate the 95 GHz band for astronomical bands, because of protection of the best observing bands. Alternative way is to reserve the millimeter-wave telescope sites as protection zones.

9. SHARING THE RADIO SPECTRUM

R. J. Cohen (NRAL Jodrell Bank)

The radio spectrum is a common resource like air or water which can be used in many ways and for many purposes. Similarly it must be shared equitably. International use of radio is regulated by the International Telecommunications Union (ITU). The scientific use of radio for passive measurements such as radio astronomy or remote sensing (passive) was introduced into the ITU regulations at a late stage, and does not fit naturally into the framework. The needs of radio astronomy are inherently different from those of most other radio users.

The power levels reaching Earth from cosmic sources are generally very low and they are beyond the astronomer's control. Large antennas and sensitive receivers are needed to detect and measure them. This makes radio astronomy particularly vulnerable to interference from man-made emissions. The cosmic emissions are often of unknown character, such is the nature of research, and this can make it difficult to distinguish the wanted signal from interference. Radio astronomy needs quiet frequency bands in which to conduct measurements of the highest sensitivity. This is best achieved by world-wide allocations of passive frequency bands. Yet many other frequency bands are also of scientific interest. Only 2% of the radio spectrum below 50 GHz is allocated to radio astronomy, and only 30allocations are passive.

As the worldwide use of radio expands, radio astronomy is increasingly going to be confined to the officially allocated bands. Concern is now mounting at the state of those bands. Real transmitters cannot confine their emissions to sharply-defined frequency bands like those allocated by the ITU. Inevitably there are unwanted emissions which spill into other frequency bands, creating a type of radio pollution. The ITU has been slow to address this growing problem of unwanted emissions. Emissions from satellites are a particular concern for radio astronomy. Just one satellite can affect radio observatories all around the world, however isolated geographically and however well-shielded from terrestrial transmitters. The ITU has no regulations on the unwanted emissions from satellite transmitters.

Examples of interference to radio astronomy from satellites are growing steadily. In the 1980s the global satellite navigation systems GPS and GLONASS became well known to radio astronomers through their unwanted emissions into the frequency bands around 1.6 GHz used to observe spectral lines of OH. The solution to such problems takes many years to negotiate and to implement, once the system is already flying. This year the Iridium communications satellite system looks set to cause interference in the very same OH band, despite the experiences of GLONASS and despite efforts to avoid a similar problem with Iridium. At higher frequencies we have the Astra satellite over Europe interfering at 10.7 GHz with observations in a passive band.

My great concern is for the future. Altogether 80% of radio astronomy bands with a worldwide primary allocation are immediately adjacent to bands allocated for satellite downlinks! GLONASS and Astra may be only the beginning. The low Earth orbitting satellites (LEOs) of the future will fly in large constellations like Iridium, so that many will be visible simultaneously. The challenge will need to be addressed at many levels, from technical to regulatory. We are not opposed to satellite systems, but we do not want their downlinks right next to our spectral lines. We cannot stop the telecommunications revolution, but we must find ways to reduce its impact on radio astronomy.

10. KEEPING THE RADIO WINDOWS OPEN

W. A. Baan (Arecibo Observatory, IUCAF Secretariat Barrio Esperanza)

Passive scientific use of the radio spectrum has become more difficult due to harmful interference from active users in other spectral bands. The time has come for national administrations and spectrum managers to re-consider the protection afforded the non-profit passive services from market-oriented commercial users. The following urgent issues need to be addressed in order to assure adequate protection for the passive users operating in the Radio Astronomy and Earth Exploration services:

1. The Radio Regulations of the International Telecommunication Union —The Radio Regulations (RR) afford protection of all spectrum users on an equal basis and do not allow preferential treatment of one particular service. However, the passive Radio Astronomy and Earth Exploration users of the spectrum only observe natural emissions that are significantly weaker than the vast majority of man-made signals. Therefore, this "equality for all" rule from the RR cannot reasonably be interpreted as equal interference levels for all. It is essential that the ITU modernize and improve its protection standards for the passive services as it introduces and regulates existing and new space-based telecommunications industries.

2. Limits of Unwanted Emissions—Unwanted emissions from other spectrum users in adjacent or far-removed bands have become a limiting factor for the use of many passive bands. Passive users are intend on lowering the limits for out-of-band and spurious emissions. Although the protection of the passive services was one of its principal objectives, ITU-R Task Group 1-3 on "Spurious Emissions" has recommended standards for WRC-97 that do little to protect the passive services. Continued efforts within a new Task Group 1-5 are required to bring the standards for unwanted emissions in line with current radio technology.

3. Space Services—The explosive growth of the use of satellites by various services offers great benefits to mankind yet the current growth in number poses an ominous threat for scientific spectrum users. Downlink emissions can be particularly damaging for ground-based astronomical telescopes and already the emissions of GLONASS and ASTRA-1D have severely curtailed observations. The new IRIDIUM system poses a similar threat. In building space vehicles the highest engineering standards should not be sacrificed in favor of economic arguments. In particular, electro-magnetic environmental impact statements and extensive testing must be required before launching space-borne transmitter systems.

4. Spectrum Bands Above 30 GHz—The increasing commercial use of frequency bands above 30 GHz poses new problems for the scientific spectrum users. In particular, the protection of spectral neighbors will require higher engineering standards and vastly improved filter technology. Regulations for high frequency bands up to and beyond 1000 GHz should take into account the lessons learned at lower frequencies to prevent similar shortcomings.

5. Spectrum Splintering—The ITU Allocation Table contains spectrum designations for many "unlike" services with different operational standards in adjacent bands. Many of these bands are rather narrow and extensive coordination is required for these users to operate together and not interfere. Even today about seventy percent of all radio astronomy bands are threatened by satellite links and still new satellite downlink allocations are sought next to passive bands. Administrations need to strive to allocate 'like" services to broader band sections and avoid further splintering of the spectrum in increasingly narrow bands.

6. Sharing Considerations—Creative time sharing and geographical sharing schemes may provide limited access to certain bands, which are allocated to other services but have scientific potential. Geographical sharing schemes will require the creation of coordination zones or quiet zones by national administrations to provide local protection from ground-based services for sensitive observatories.

Peaceful coexistence in the spectrum for passive and active services is possible and depends on mutual respect for each other's activities. As spectrum occupation increases, the need to protect all passive and active spectrum users becomes more urgent. Only by mutual understanding and cooperation can we keep the radio windows to the Universe open and clean and in reserve for passive use by future generations.

11. THE SPACE DEBRIS ENVIRONMENT OF THE EARTH, AMOUNTS AND GROWTH

W. Flury (ESA/ESOC)

Since 1957, more than 3800 launches have led to more than 8000 trackable objects currently in orbit around the Earth. Surveillance, that is detecting and tracking space objects with radar, optical and infra-red sensors, is carried out by the space surveillance networks of the United States and Russia. The trackable objects have typically a minimum size of about 10 cm at low altitude and about 1 m at the geostationary orbit. Of the large number of catalogued objects fewer than about 500 are operational satellites. The remainder are abandoned satellites (21%), upper stages (16%), fragments of satellites and upper stages (45%), and mission-related objects (12%) such as lens covers, separation bolts or clamp-bands. A much larger number of smaller objects—unobservable by routine space surveillance—maybe 100,000 to 150,000 larger than 1 cm and thus capable of damaging a spacecraft, is in orbit. With special campaigns of powerful radar facilities,

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e.g. Haystack, FGAN, or the combined use of FGAN with the 100 m Effelsberg radio telescope, statistical information on 1 cm size objects in Low-Earth orbit (LEO) can be gained.

With an uncontrolled growth orbital debris could become a major hazard for all human activities in space. Already now orbital debris is a potential risk in two important regions, namely at low Earth altitude, and in the geostationary ring. An indication of the degrading quality of the space environment are the first confirmed collision of an operational spacecraft (Cerise) with a rocket fragment, avoidance manoeuvres of the US Space Shuttle and of unmanned spacecraft in LEO, and the more than 60 replacements of windows of the US Space Shuttle damaged by impacts of small-size debris and meteoroids. Space debris is also degrading astronomical observations as large scale exposures of the sky may contain satellite trails.

This presentation will provide an overview of the terrestrial space debris environment. Sources for the catalogued objects and small-size space debris will be reviewed. Models for the spatial distribution will be presented. Explosions and collisions as the main debris sources will be addressed. Finally, the long-term evolution and debris reduction measures will be reviewed.

12. ENVIRONMENTAL DISTURBANCES OF ASTRONOMICAL OBSERVATIONS

J. Kovalevsky (CERGA, Observatoire de la Côte d'Azur)

This presentation is aimed at describing several effects, generally of geophysical origin, which contribute, in addition to sky glow or electromagnetic wave interferences, to degrade astronomical observations from the ground.

The efficiency of an astronomical instrument must be considered together with all the atmospheric layers crossed by the incoming light. This optically active element affects the shape of the image and the apparent direction of the observed celestial body. Astrometric measurements may be significantly biased by un-modelled spurious refraction effects. But the most important source of disturbances is the local atmospheric turbulence which is the major factor of astronomical seeing. The height of the boundary layer is function of the existence of heat sources. In day-time, it is governed by the Sun, but in night-time, the presence of buildings, roads, vegetation of various types, has a definite influence on the quality of the atmospheric images, increasing their unstability and introducing sometimes an inclination of the atmospheric layers, causing abnormal refraction.

The chemical composition of the atmosphere has evidently a direct effect on spectroscopy. This is particularly important in millimeter and submillimeter band astronomy, in the research of various interstellar or circumstellar molecules. The atmospheric emissions and opacity in this wavelength domain are major perturbations in recognizing the spectral lines of these extraterrestrial emissions. Increase in opacity may also occur after major geophysical events such as aerosols or dust from volcanos.

Optical interferometres are very sensitive to any perturbation of the optical path lengths. This can be produced by deformations of the wavefront due to turbulence, and particularly long period deformations in the higher atmospheric layers. Another cause is the variation of the baseline, consequence of seismic activity. Very significant perturbations are produced by oceanic waves which and are important even several hundreds of kilometers away. Storms on the ocean may be sources of important deterioration of interferometric observations.

Some of the atmospheric dynamical effects may be compensated using active or adaptative optics. It has however to be noted that these techniques correct the wavefront only within a few arc seconds. This is certainly the solution when a single star is being observed, but does not apply for larger field studies. It is also conceivable that is the future, interferometric baselines could be corrected in real time from seismic simultaneous readings. Millimetric and submillimetric observations can get rid of a large part of spectroscopic pollution in hight altitude sites. But most of the ground based astronomical observations will continue to be highly sensitive to these environmental perturbations.

13. THE AVOIDANCE OF MAN-MADE POLLUTION IN INTERPLANETARY SPACE

C. S. L. Keay (University of Newcastle)

At the 20th General Assembly of the International Astronomical Union in Baltimore, U.S.A., in 1988 members of Commission 22 and several Commissions in what is now the Division of Plan-

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etary Sciences expressed deep concern that no work was being undertaken to identify and avoid pollution problems in interplanetary space. Commission 22 set up small a working group with I P Williams as convenor. It identified several problems requiring further study and recommended further investigation.

At the 22nd General Assembly in The Hague in 1994 a formal Working Group on The Prevention of Interplanetary Pollution was set up with members from each of the Commissions in the Division of Planetary Sciences. Care was taken to include members from each of the international powers with a presence in space operations and research. Astronomers from Australia, China P R, the Czech Republic, France, Japan, the Russian Confederation and the United States of America. Largely through e-mail contact the convenor, C S L Keay, drew on the expertise among the nominated members to expand the earlier report.

The principal areas of concern dealt with by the Group are:

* Environmentally harmful propellant residues;
* Unconfined debris from impacting objects;
* Pollution from explosives, particularly nuclear;
* Radionuclide pollution from nuclear power generators;
* Undesirable transfers of surface materials;
* Biocontamination prevention and quarantine measures.

It was stessed that the challenge is to devise cost-effective techniques and procedures acceptable to mission planners which will prevent or at the very least minimise pollution outcomes. To achieve success a program of careful preliminary research will be necessary, paying attention to the following points in regard to all aspects of space missions:

* Identify likely sources of undesirable pollution;
* Measure present levels and predict future levels;
* Assess future impact of pollution on research goals;
* Investigate likely severity and irreversibility;
* Formulate preventative or minimisation procedures;
* Set guidelines for assessing preservation values;
* Develop means to protect sensitive environments;
* Seek ways to increase awareness of the issues.

The working Group recommended the establishment of an international scientific committee to involve all relevant agencies and draw up suitable procedures and protocols for achieving success. It should be very much less costly to be proactive in this endeavour than to allow permanent harm to sensitive regions of the interplanetary environment.

14. THE PROCESS OF FREQUENCY MANAGEMENT, INTERNATIONAL TREATIES AND THE RESPONSIBILITY OF ASTRONOMERS

J. Tarter (SETI Institute)

Working with national and international regulatory bodies to allocate the radio spectrum, and monitoring regional applications for spectrum usage are increasingly becoming the cost of doing radio astronomy. Economic incentives are enormous, with new services constantly seeking additional allocations within the radio spectrum. Radio astronomers cannot depend on the goodwill of for-profit service providers to keep portions of the spectrum free for the use of the passive services (radio astronomy and remote sensing). At present, a small number of senior scientists and managers are struggling against this tide. They should not only be praised, and thanked, but joined. It is imperative that current and future generations of radio astronomers learn the business of frequency management and participate in the distribution of this scarce resource.

15. EDUCATING THE PUBLIC ABOUT PRESERVATION OF THE ASTRONOMICAL WINDOWS

W. T. Sullivan, III (Univ. of Washington)

If astronomers are going to succeed in their efforts to keep the skies free of light pollution and radio interference, then they must deal not only with lighting and radio engineers, business concerns, and politicians, but also the general public. If the public becomes persuaded that clear, pristine skies are worth having for the same sorts of reasons that we value drinkable water and breathable air, then we have gained the most important constituency. It is, after all, the public who pay the taxes, who buy the products, and who vote in elections. Just as with other environmental issues, if the public is won over, then the engineers and policy makers (eventually) must follow along.

In this paper I highlight efforts around the world that have been particularly noteworthy in the cause of reducing light pollution by educating the public. Radio interference is also of great harm to astronomers, but it will be covered only briefly in this paper because very little has been done to educate the public about the radio problem. This is because radio pollution is a more abstract and technical concept for the average person, as well as because many of the problems are addressable at the international (World Telecommunications Union) and national levels. With light pollution, however, the battles are more often on a local stage.

The premier organization fighting light pollution and educating the public about it is the International Dark-Sky Association (www.darksky.org/ ida/index.html), based in Tucson, Arizona, USA, and with over 2000 members in 69 countries. Over the past ten years IDA, largely through the person of David Crawford, has been able to not only preserve dark skies for observatories, but more significantly convince a great number of lighting engineers and public officials that it's in their own best interest to use lighting systems that are also beneficial to astronomers. Exterior lighting for streets and buildings that does not shine upwards saves a great deal of money, does its job much more efficiently and safely, and is aesthetically more pleasing. An alliance has been forged between those on all sides who are "enlightened" and it is steadily growing in its size and influence. For the cause IDA has produced 7 slide sets, 120 information sheets, and 2 videotapes.

The best way to check other major efforts around the world is to visit the Web sites linked to IDA's site. For example, in the United Kingdom the Campaign for Dark Skies (CDS) has also been effective in its educational and political efforts. Their booklet Starry, Starry Night, produced in conjunction with the Council for the Protection of Rural England, is first-rate in promoting dark skies and good lighting practices. CDS has also promoted "Star Watch UK", a project for schools and other youth groups to count the stars visible in a well-defined area of the sky. This type of program has also been done in Canada and the USA, and especially in Japan, where it was funded by the national Environmental Agency. Based on these amateur data, maps were constructed for sky brightness all around Japan. Even more than the maps, the real value of such projects is the increased awareness they bring to the public of deteriorating sky conditions. Many other examples, from countries such as Switzerland, Holland, Italy, and Spain, are discussed in the full paper.

16. PUBLIC EDUCATION TO PRESERVE DARK SKIES AND ASTRONOMICAL WINDOWS WITH EAVESDROPPING AND ROBOTIC TELESCOPES

J. E. F. Baruch (Robotic Observatories)

Abstract

It is suggested that the only guarantee for the preservation of dark skies is the guarantee that exists in the hearts of the people around the world. This paper notes how rising living standards and increasing GNP are associated with light pollution destroying the heritage of the night sky. It argues that it is necessary to decouple light pollution from rising living standards. A contribution to this process is to provide indices that are easily understood and useable for measuring the quality of the night sky.

It is shown how robotic telescopes can provide access to the night sky for people in the developed world through programmes which provide education, involvement in astronomy research and access to the leading edge of astronomy through the new technique of eavesdropping. These education programmes will help to bring an understanding of the value of our heritage that belongs to our grandchildren: The Night Sky.

17. THE ISSUES OF SPACE DEBRIS AND NEAR-EARTH OBJECTS AT THE UNITED NATIONS

H. J. Haubold (United Nations Office for Outer Space Affairs)

The focal point of the United Nations activities in the field of peaceful uses of outer space is the Committee on the Peaceful Uses of Outer Space (COPUOS), set up in 1959 by the General Assembly. Since its establishment, the Committee and its two subcommittees (the Scientific and

Technical Subcommittee and the Legal Subcommittee) have resulted in five legal instruments, all of which have entered into force, as well as four sets of principles adopted by the United Nations General Assembly on the conduct of space activities, including astronomical satellite missions (http://www.seas.columbia.edu/ ah297/un.html):

1. Treaties

The 1966 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies ("Outer Space Treaty") provides that space exploration shall be carried out for the benefit of all countries, irrespective of their degree of development. It also seeks to maintain outer space as the province of all mankind, free for exploration and use by all States and not subject to national appropriation. The 1967 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space ("Rescue Agreement") provides for aiding the crews of spacecraft in the vent of accident or emergency landing, and establishes a procedure for returning to a launching authority a space object found beyond the territorial limits of that authority. The 1971 Convention on International Liability for Damage Caused by Space Objects ("liability Convention") provides that the launching State is liable for damage caused by its space objects on the Earth's surface or to aircraft in flight and also to space objects of another State or person or property on board such objects. The 1974 Convention on Registration of Objects Launched into Outer Space ("registration Convention") provides that launching States shall maintain registries of space objects and furnish specified information on each space object launched, for inclusion in a central United Nations Register (maintained by the United Nations Office for Outer Space Affairs). The 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies ("Moon Agreement") elaborates in more specific terms the principles relating to the Moon and other celestial bodies set out in the 1966 Treaty and sets up the basis for the future regulation of exploration and exploitation of natural resources found on such bodies.

2. Principles

The Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space (1963). The Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting (1982). The Principles Relating to Remote Sensing of the Earth from Outer Space (1986). The Principles Relevant to the Use of Nuclear Power Sources in Outer Space (1992).

3. Space Debris

Space debris are all man-made objects in Earth orbit or reentering the dense layers of the atmosphere that are non-functional with no reasonable expectation of their being able to assume or resume their intended functions or any other functions for which they are or can be authorized, including their fragments and parts. The item on space debris was included into the agenda of the Scientific and Technical Subcommittee at its 1994 session; since 1995 the Subcommittee continued its consideration of this item on a priority basis. Member States and relevant international organizations are currently providing information on practices in minimizing the creation of space debris and the effects of this environment on space systems, including those used for astronomical purposes (`http://www.un.or.at/OOSA_Kiosk/`).

4. Near-Earth Objects

Pursuing an understanding of Earth's interactions with near-Earth objects and adverse environmental impacts on astronomy have become issues of global research. In an effort to provide a scientific basis for future cooperative international research and space exploration, The Explorers Club and the United Nations Office for Outer Space Affairs organized an international conference on near-Earth objects (A. Carusi, T. Gehrels, and S. Isobe in Near-Earth Objects: The United Nations International Conference, Ed. J. Remo, Annals of the New York Academy of Sciences 822 (1997) 632 pp.). The forthcoming United Nations Conference on the Exploration and Peaceful Uses of Outer Space in 1999 at Vienna, Austria, may provide a forum to review such issues in depth.

The views, interpretations, and opinions presented in this paper do not necessarily reflect the position of the United Nations.

18. BILATERAL AGREEMENTS, ZONING, INTERNATIONAL PROTOCOL

S. Isobe (National Astronomical Observatory)

It is clear that conditions of astronomical observations become worse and worse : those are light pollution, radio interference, and space debris. However, causes of these worse astronomical conditions are created to make human life convenient. Therefore, our problems can not be solved straightforward. An way which astronomers have managed to keep good observational conditions is to escape from residential areas to country areas and to mountain areas, and may be in future to back side of the moon. An expansion of cities has produced bright sky glow because of unproper usage of lighting instruments and an increase of necessary radio bands for daily life has produced the higher level of radio noise for astronomical observations. Launching of useful satellites has produced large number of space debris.

In these situations it is hard to keep conditions of astronomical observations in a good shape only by efforts of astronomers. We have to work together with other organizations to develop a channel reaching to the majority of people. For a space debris problem, there are the IAD (Inter-Agency Space Debris coordination) composed of space agencies from many countries such as NASA, ESA, NASDA, ISAS, Russian one, and Chinese one, specialists for space debris at each organization are worry about debris collisions to working satellite near future, but decision makers do not consider it at a severe situation. Astronomers should work with those specialists. For a problem of radio interference, there are COSPAR, ITU, and URSI with which astronomers should work together.

For a problem of light pollution, there is CIE(Commission Internationale de l'Eclairage) with which IAU Commission 50 now jointly sets up a Technical Committee 4-21 under the CIE. To compromise requests by observational astronomers and lighting engineers, an idea of zoning was proposed by Paul Murdin in 1992 and is now included a guide line of CIE TC4-21 "Interference by Light of Astronomical Observations".

To make people realize difficult conditions of astronomical observations, astronomers themselves should produce scientific evidences to show the difficulties. Unfortunately, some certain fractions of astronomers do not show any interest in the problems. We should concentrate our efforts and set up international protocol. For the light pollution, the CIE Division 4 passed a resolution to minimize air glow in October, 1996, the IAU GA passed a resolution to support the CIE one in August, 1997. Then, it is expected that the CIE GA will to pass it in 1999, which will be a starting point to bring it as the ISO standard. When this international protocol will be once set up, all the governments will take different actions to reduce sky glow under the idea of zoning.

Astronomers can directly be against people producing useless light, but it is usually hard work since many people enjoy bright lighting. It is much short way to minimize light pollution that international protocol such as the ISO standard is set up. We can find out a similar way for problems of radio interference and space debris.