POLICY FORUM: SPACE SCIENCE

# Astronomy and the Degrading Environment

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Our understanding of the universe is advancing dramatically, primarily because we can now observe the cosmos at all wavelengths of the electromagnetic spectrum with instruments of enhanced and continually improving sensitivity.

The public is extremely curious about the state of our universe and expects to see spectacular images and hear about great discoveries often. Yet, accelerating man-made degradation of the environment may ruin the goals of astronomers and dampen the curiosity and expectations of the public: Ground-based light pollution is making the sky harder for everyone to see, and space junk and radio noise from the sky are increasingly blinding astronomers at other wavelengths, too. As we move from an era dominated by government-operated space agencies to free market forces and deregulation, these problems threaten to increase dramatically.

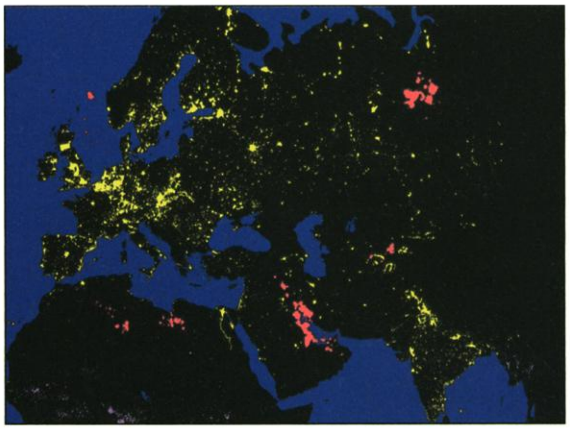
**Lights in the night sky interfere with astronomical observation.** False-color image of the eastern United States as seen from the U.S. Defense Meteorological Satellite Program (DMSP) spacecraft (*3*).

## Infinite Space?

Although the universe is infinite, outer space, which is touted as an endless frontier for lucrative business, is in reality just a thin shell around Earth, where we have the ability to place stable satellites. Satellites in low Earth orbit (LEO) can reach a maximum altitude of about 5500 kilometers, which is just 10 to 15% of Earth's radius, whereas satellites in geosynchronous orbit (GEO) can reach a maximum altitude of about 36,000 km, which is less than 1/10 of the distance to the moon or 1/4000 of the distance to the sun—trivial by cosmic standards. Thus our boundless outer space is really minuscule compared with the size of the universe we try to observe.

We obtain information about the universe from visible, ultraviolet or infrared light, energetic particles, and radio waves. Most of these signals are received through ground-based instruments and telescopes that peer through the thin layer of our atmosphere or from orbiting spacecraft.

Whether reaching us from the Milky Way or from the edge of the universe and the beginning of time, these signals are incredibly faint because of the unfathomable distances involved. To record them, we need instruments and detectors with extreme sensitivity. As just one example, the total radiation collected by all the world's radio telescopes during the last half century would suffice to light an ordinary flashlight bulb for a millisecond.



**False-color image of Eurasia at night,** based on satellite data from the DMSP spacecraft (yellow, city lights; red, flares from oil production areas; purple, burning vegetation).

However, as our instruments improve, man-made interference at all wavelengths keeps rising steeply. An increasing share of the signals from the universe are drowned in man-made noise on the last tiny leg of their long odyssey.

## Man-Made Interference

Environmental problems for astronomy fall in four broad categories (*1*): ground-based light pollution, radio frequency interference, space debris, and other space activities.

Light pollution is the most common and easily recognized form of man-made interference (*1*, *2*). Modern city dwellers hardly know what stars look like, let alone the magnificent stellar panoply of a truly dark sky. Although local light pollution is familiar, the global extent of the problem is best seen from space (see the figures). The light that appears so bright is scattered back into telescopes and prevents observations of faint objects, be they faraway galaxies or small, near-Earth asteroids.

However, the light seen from space also represents a waste of energy and money, as well as more greenhouse gas and/or radioactive waste. The glare from poorly designed lighting fixtures can blind rather than help people see objects better. Worse, without darkness, nocturnal animals go astray or disappear, disturbing delicate ecosystems. As cities grow, so does the need for light, but rational lighting design, which directs light onto the object to be seen, rather than into people's eyes or into the sky, can prevent additional pollution and waste (*3*).

Radio astronomy faces an even more acute problem of interference from man-made radio transmissions. If Neil Armstrong had taken one of today's cellular telephones along to the moon, it would have been one of the four brightest radio sources in the sky. The radio signals from remote galaxies are millions of times fainter than this.

International agreements negotiated by the International Telecommunications Union (ITU) (*4*) allocate some important frequency bands to radio astronomy. This worked well when we could observe only the local universe where everything is nearly at rest with respect to us. As technology improves, so that we can observe more distant galaxies and quasars, a wider range of radio frequency bands is needed. Moreover, low-level unwanted emission

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(noise) from communications satellites far from their nominal frequency may still obliterate the astronomical signals, and international standards and limits on such emissions do not exist. Already, communications with satellites for natural disaster warning and for remote sensing of Earth and its atmosphere, as well as global positioning system (GPS) satellites, have experienced interference from crowding of the radio spectrum (*5*).

Space debris, such as spent satellites, launch vehicles, and other satellite fragments, is another problem of increasing severity (*6*). The total amount of debris is 2 to 3 million kg, with some 8000 objects in cataloged orbits, at least 100,000 pieces more than 1 cm in diameter, and untold millions of smaller bits crisscrossing GEO and LEO. As more satellites are launched and pieces collide, the amount of debris can only grow, and no cleanup method is known.

At typical speeds of 20 km/s—30 times that of a rifle bullet—even a 1-cm piece of debris can severely damage manned and unmanned spacecraft. The International Space Station would have a higher probability of being hit than most other spacecraft because of its planned size and time in orbit. Two scientific satellites have already been destroyed by space debris (*5*). Moreover, sunlit space debris also leaves bright streaks on astronomical images taken from the ground (*1*).

## Upcoming Attractions

Space activities planned for the next decade include projects of unknown environmental impact (*5*, *7*), that may be disastrous for astronomy and space services providing remote sensing or communications. Examples include space art, advertising, and power generation and transmission devices that can be placed in LEO. They have not yet caused serious problems, but enough projects have been described in detail or brought to the pilot stage that action should be taken to consider their consequences before it is too late.

Another concern are space mirrors designed to illuminate parts of Earth or to beam down energy captured in space. Prototypes have been tested [e.g., the Znamya 2.5 mirror in February 1999 (*8*)], so far with little success, but ambitious plans exist. Because they provide an almost direct view of the sun, damage to wildlife or even human eyes is possible. In principle, experiments can be confined to a nation's own territory and jurisdiction, but adequate government control may not be exercised, leading to potential disasters for the country and the larger international community. The UN space treaties (*9*) do make a nation liable to other nations for damage caused by its space activities, but the globalization of business makes the legal situation unclear, and loss of scientific data is not covered.

## Remedies

Some remedies for these problems are easy to advocate: Replacing bad lighting fixtures with improved designs provides safer lighting, helps astronomy, and brings a net return in energy savings in 3 to 4 years (*3*). The citizens of Tucson and the astronomers from nearby Kitt Peak National Observatory both profit from a wise lighting policy. The International Dark-Sky Association (*3*) is working to help other cities benefit from this experience. New observatories can be located in protected areas, remote from ground-based light and radio interference.

Some remedies will be harder to implement, however. Each year, more than 100 satellites are launched with the goal of providing telecommunications to every corner of the globe. Remote, quiet radio observatory sites will soon cease to exist because of these satellites. Internationally protected radio quiet zones are needed, and satellites must be designed to avoid emitting at unwanted radio frequencies or in the wrong directions.

Space agencies are developing techniques at least to reduce the rate of growth of space debris. However, significant technology development may be needed to design spacecraft that create a minimum of debris or unwanted radio emissions, and implementing such measures may increase mission costs. Space agencies invest for a long-term future in space, but commercial launches focused on short-term profit are not required to take similar environmental measures as the space agencies.

## Action Needed

Man-made degradation of the space environment is global in cause and effect. Mitigation requires cooperation among nations. We need internationally recognized emission standards and environmental traffic rules in space as on Earth, to secure a sustainable future for business and science in space. It will also be necessary to monitor the environmental impact of all space activities. Our governments are responsible for defining such rules, as well as establishing and coordinating monitoring, in a timely way.

To bring this message to all nations, a special environmental symposium, *Preserving the Astronomical Sky* (*7*) was sponsored by the International Astronomical Union (IAU) in 1999. It was organized jointly with the Committee on Space Research (COSPAR) and the UN Office of Outer Space Affairs and was held in parallel with the United Nations conference UNISPACE III, convened to formulate policies for space over the next 20 to 30 years. The symposium and the conference brought together members of several relevant communities who discussed problems and solutions for space pollution.

Based on the findings of the IAU symposium, the final report of UNISPACE III (*10*), approved by all 100 nations, recommended in summary that "space activities which may have harmful effects on the local and global environment should take appropriate measures to limit such effects"; that "the space environment should be protected through research and implementation of mitigation measures for space debris"; and that "all users of space consider the consequences" of their projects "before further irreversible actions are taken," specifically listing "interference from unwanted radio emissions with radio astronomy and space research" as an "issue of concern."

This moral support must be turned into action. Accordingly, the IAU will continue to work with other scientific unions, space research organizations, and interested nations to develop coherent, science-based, practical standards and measures that can be considered for adoption by the UN Committee on the Peaceful Uses of Outer Space and the ITU and other international bodies managing radio frequencies. In the same vein, the Organization for Economic Cooperation and Development (OECD) Global Science Forum is considering procedures by which nations can avoid investing in radio observatories and simultaneously ruining them through other activities.

Environmentalists have shown how popular opinion may influence governments and industry to weigh long-term sustainability against short-term profit. Astronomers worldwide fervently hope that this spirit will be applied to space before it is too late.

### References and Notes


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4. See www.itu.int
5. A. Otchett, *UNESCO Courier*, June 1999, p. 10.
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