Taking Back the Night

The bad news is that the astronomical environment is steadily being degraded; the good news is that the astronomers have allies

LIKE THE GREAT BARRIER REEF or the Amazonian rain forest, the Night is a huge, but fragile resource. And for astronomers, it is a resource that is steadily slipping away—a victim of light pollution, radio interference, and even satellite tracks.

"If we don't do something," says David L. Crawford of the National Optical Astronomy Observatory, president of the International Astronomical Union's (IAU's) commission on the protection of observatory sites, "we face the specter of a future when *no* one can see the universe except in a planetarium."

Other astronomers echo the point. The good news, they say, is that all three problems can be controlled—at least in principle—and that they often have allies in helping them do so. The bad news is that the pressures on the astronomical environment are as incessant as the pressures on the earthbound environment. Indeed, to judge from the stories being told at the recent congress of the IAU in Baltimore,* and again at a special-purpose IAU colloquium held immediately thereafter in Washington, D.C.,† the threats have escalated markedly in the past decade or so. A sampler:

■ The Soviet Union's new system of GLONASS military navigation satellites transmit on a set of radio frequencies that blanket the 1612-megahertz emission line of the hydroxyl radical (OH), a common constituent of the interstellar medium and one of the best tracers available for mapping activity in the galaxy's star-forming regions.

*The 20th General Assembly of the International Astronomical Union, 2 to 11 August 1988, Baltimore.
†IAU Colloquium 112, "Light Pollution, Radio Interference, and Space Debris," 13 to 16 August 1988, Washington, D.C.

On any given day, points out John Galt of the Dominion Radio Astrophysical Observatory in Pinticton, British Columbia, about half the observations at this frequency have to be discarded; the GLONASS transmissions are so powerful that the interference is detectable no matter where the telescope is pointing so long as there is even one satellite above the horizon. (A similar, albeit lesser, problem exists with GLONASS' American counterpart: the Pentagon's Global Positioning Satellite system, now being readied for the 1990s, will interfere with observations of the red-shifted 21-centimeter hydrogen line in distant galaxies and quasars.)

The GLONASS system is still incomplete, fortunately, which means that several hours per day are still interference free. But when and if the system is brought up to its full complement of 24 satellites in the 1990s, the hydroxyl window will be shut. Western astronomers—and reportedly Soviet astronomers as well—have sent repeated messages to the Soviet Academy of Sciences, asking that the academy use its influence in getting the GLONASS frequencies changed in the future. It remains to be seen how much effect the complaints will have.

■ According to Paul G. Murdin of the Royal Greenwich Observatory, astronomers at the United Kingdom Schmidt telescope in Australia now find that "all exposures made within about 2 hours of sunrise or sunset have satellite trails, with an average of five trails [per photograph] and some cases of ten or more." Granted that most major telescopes take in a much narrower slice of the sky than the Schmidt—its 6° field of view is 12 times the width of the full moon—the probability of catching a satellite in any given image is still far from negligible. An ill-placed satellite track can ruin an image that cost thousands of dollars to make, says Murdin, not to mention wasting precious telescope time. Worse, if a satellite were to reflect sunlight into the telescope when observers were using one of their most sensitive light detectors—some of which come close to counting individual photons—the detector might well be destroyed.

■ The optical astronomers' most pervasive and worrisome problem, light pollution, continues to be as inexorable as urban sprawl. It has noticeably affected virtually every professional observatory in the world—not least because observatories have to be located fairly close to population centers for logistical reasons. At the Kitt Peak National Observatory, some 100 kilometers west of fast-growing Tucson, for example, the night sky is now 6.5% brighter than it would be naturally. Atop Palomar Mountain, 80 kilometers northeast of San Diego, the night sky is 100% brighter than natural background—meaning that the flagship 5-meter telescope is effectively a smaller instrument that it ought to be.

Even more insidious than the shear quantity of light, however, is the *kind* of sky glow now being produced by the cities. The old-style mercury vapor lights are at least tolerable: they make everything seem cold and eerie precisely because their radiation is concentrated into a relatively small number of spectral lines, which the spectroscopists can simply ignore. But the newer high-pressure sodium lights—the ones with the warm, amber-pink color—are an astronomical disaster: their radiation is spread over a broad continuum of wavelengths that the spectroscopists *cannot* ignore. And unfortunately for the astronomers, that same warm quality of the high-pressure sodium lights has made them very popular. During the past decade or so, they have been installed by the thousands in parking lots and along highways all over the country.

In summary, then, the state of the astronomical environment is disturbing. More-

Sky glow. *Tucson, Arizona, as seen from the Kitt Peak National Observatory: in 1959 (top) and in 1980 (bottom).*

over, there is no easy escape: light pollution would not be a problem for telescopes in orbit or on the moon, for example. But if the Hubble Space Telescope is any guide, such facilities will cost at least 1000 times what they do on the ground—which means that very few of them are going to be built anytime soon.

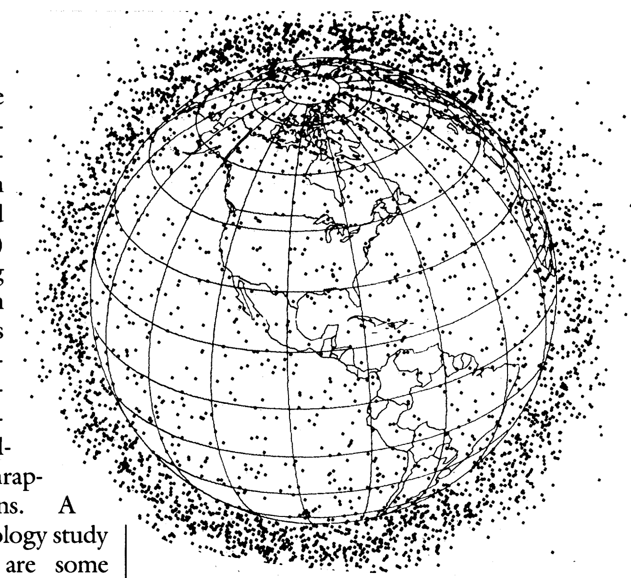
Still, the mood at the Baltimore and Washington meetings was not completely downbeat. Not only can the astronomers point to at least partial solutions in all three problem areas, but they often seem to have powerful natural allies with an interest in seeing those solutions implemented. Furthermore, they are learning how to make those alliances pay off.

Perhaps the most vivid example of this is light pollution, where the astronomers' natural ally is simple economic self-interest: cutting back on light pollution—without compromising on the light that people actually need—can save a lot of money. Indeed, says Crawford, once the advantages are pointed out, local governments tend to be quite receptive to the astronomers' pleas for outdoor lighting regulation. San Diego County has now enacted strict lighting ordinances for the area around Palomar, for example, and in Arizona, similar laws govern Phoenix, Tucson, and most of the rest of the state's population.

To get a feel for the savings, he says, consider that roughly $1 billion worth of electricity is wasted in the United States every year on "lighting up the underbelly of airplanes." Particularly egregious are sports stadiums, and even worse are the unshielded, upward-pointing lamps commonly used to illuminate advertising billboards: most of the light is thrown up into the sky, and only a portion, almost by accident, actually hits the sign. Much of that wasted money can be saved—and much of the astronomers' problem solved—when the fixtures are equipped with hoods and reflectors that put the light where the users wanted it in the first place: on the ground or on the signs.

As for the quality of the light, says Crawford, there turns out to be a happy alternative to the high-pressure sodium fixtures, especially for highway lighting, security lighting, and other applications where color is not important. These *low*-pressure sodium lights, recognizable by their monochromatic yellow color, are 40% more energy efficient than their high-pressure counterparts. (Indeed, they are fast becoming the fixtures of choice on purely economic grounds.) And at the same time they are far less threatening to astronomical spectroscopy: they emit virtually all their energy in the yellow sodium doublet line, which is trivial to discount.

In another problem area, that of satellite tracks, the astronomers' allies are also powerful: the sharply increasing level of orbital debris is becoming a real concern for both the National Aeronautics and Space Administration (NASA) and the U.S. Air Force, among others. The North American Aerospace Defense Command is currently tracking some 6000 orbital objects that are 10 centimeters in diameter or larger, including functioning and derelict satellites, spent rocket casings, and shrapnel from various explosions. A Massachusetts Institute of Technology study recently estimated that there are some 48,000 objects 1 centimeter or larger. And the average relative velocity of those fragments is roughly 10 kilometers per second, about an order of magnitude faster than a rifle bullet. Soviet cosmonauts can reportedly hear particles of debris hitting the side of their Mir space station, and NASA has recently begun a study of how to armor-plate its own space station. The Air Force (and presumably the Soviet military as well) is likewise concerned that a piece of junk might knock out one of its surveillance satellites at a crucial moment.



A halo of junk. *Some of the 6000 orbiting objects being tracked by the North American Aerospace Defense Command are shown here in their positions at a certain instant on 1 April 1988. Only about 5% are active satellites.*

Thus, there seems every reason to believe that the space-faring nations will take steps to control satellite debris for purely operational reasons. NASA already tries to minimize explosions in space by venting the unused fuel from spent upper stages, and other such practices. The Air Force has made it a policy to conduct any and all Strategic Defense Initiative tests at a relatively low altitude, so that the debris will reenter the atmosphere quickly. An interagency working group to study further control of space debris was formed in Washington earlier this year, and is working closely with a similar group within the European Space Agency. And there are hints that even the Soviets, who have produced more satellites and more debris that everyone else put together, are beginning to address the issue.

So that leaves radio interference. In this case, it might seem that the astronomers' allies are far outnumbered by their competitors. After all, the allocation of the radio spectrum is a classic zero-sum game. But even here the situation is far from bleak. As pointed out by Tomas Gergely, head of spectrum management for the National Science Foundation, the radio astronomers have a long-established working relationship with the communications authorities, especially in the United States, and have generally gotten a sympathetic hearing.

A good recent example is the U.S. Customs Service's plan to deploy a network of tethered balloons along the Mexican border, with each balloon carrying a downward-looking radar to search for low-flying aircraft smuggling drugs: an amicable negotiation on the choice of radar frequencies averted potentially severe interference with the Very Large Array in New Mexico. More generally, says Gergely, the Federal Communications Commission and the Interdepartmental Radio Advisory Commission—which respectively regulate private and federal uses of the radio spectrum—have been quite cooperative about not assigning certain frequencies to television stations, radio stations, and other fixed transmitters near the observatories.

Satellite transmissions, however, are something else again. The stumbling block here is not regulation per se: satellite frequencies are allocated by the International Telecommunications Union, an agency of the United Nations. Nor is it a lack of sensitivity to the radio astronomers' concerns: the IAU regularly issues an updated list of astronomically significant frequencies and every effort is made to accommodate them. The problem is that only the primary frequencies are regulated; the side bands—that is, a transmitter's spillover into nearby frequencies—are not regulated. Thus, the GLONASS system is perfectly legal because its primary frequencies technically avoid the 1612-megahertz hydroxyl line. And yet it actually swamps that line because none of the satellites' transmissions are as carefully filtered as they might be. A relatively small technical fix could change all that on future satellites. But pending a change in the international regulatory policy, it is not clear when that will happen.

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