SCIENCE NEWS OF THE WEEK

Starbursts and Gasjets: High-Energy Astronomy

"High-energy astronomy" may mean observations that record high-energy radiation such as X-rays or gamma rays. It may mean observations of astrophysical processes that involve greater energies than most. Or it may mean simply "strange astrophysics." All three points were evident in topics discussed in a special session at last week's meeting of the American Astronomical Society in Calgary, Alta., Canada.

Starbursts are one way to try to account for the large amounts of energy observed coming from very small regions in the centers of a number of galaxies. They might be a way to interpret Seyfert galaxies, a large class of galaxies with very active nuclei that fascinate a lot of astronomers. Starbursts, as D. W. Weedman of Pennsylvania State University described them at the session, are massive and extraordinary outbursts of star formation, for example 100,000 stars of spectral classes O and B in quite a small volume (and quite a short time).

For a first example Weedman cited the galaxy NGC 7714. This is a galaxy with a bright nucleus, but it's not a Seyfert. Its spectrum shows evidence of ionization, the presence of ionized gas. This is a typical product of stars, and leads to the suspicion that a lot of stars are present. That was confirmed by recent observations by the International Ultraviolet Explorer satellite, which found dark absorption lines in NGC 7714's ultraviolet spectrum that are characteristically made by mass flowing out of class O stars. "Thanks to this new generation of high technology stuff we could say we were seeing a starburst galaxy," Weedman says.

NGC 7714 is also a radio source putting out 13.5 megajanskys of radiation from a region only 1.5 seconds of arc across on the sky. (This corresponds to about 250 parsecs or 900 light-years in actual distance.) It is also a weak X-ray source, as the Einstein observatory determined. It is therefore not a Seyfert (which would have stronger X-ray emission), and it most likely does not have a nonthermal source of radiation in its center.

Without a nonthermal source, the radio and X-rays have to come from supernova remnants, which are clouds of matter blown outward from the point where a star has ended its life in a supernova explosion. It is reasonable to expect many supernovas because stars cannot last very long under starburst conditions. About 10,000 supernova remnants in the nucleus of NGC 7714 can account for the observed radio and X-ray flux. That figures out to about one supernova a year. Starbursts may be the location of the majority of supernovas in today's universe and may have seen an even larger proportion in the past. Weedman says. An interesting physical question is what happens as 10,000 supernova remnants bump and collide with each other in such a small volume. It hasn't been figured out yet.

Starburst activity may happen also in regions of galaxies that are interacting, that is, colliding with each other. Or if the colliding galaxies are small, intense star formation may pervade the whole galaxy instead of just limited regions. A question from the floor elicited the opinion that the Magellanic Clouds, which show intensive star formation throughout their volumes, may be starbursting because they are about to interact with our galaxy.

SS433 is a starlike object inside our own galaxy. Its spectrum in visible light shows evidence for three separate components, one relatively stationary and two that appear to be moving back and forth. Theorists have supposed that SS433 is a star or stellar system that is ejecting matter in rotating streams (SN: 3/1/80, p. 140).

Extremely detailed radio maps of SS433 have been made during the past year and a half with the Very Large Array of radiotelescopes near Socorro, N.M. R. M. Hjellming of the VLA staff reported the results.

The radio contours show corkscrews of matter stretching away from the center. This is best explained by ejection from a rotating source, ejection that occurs at 80° to the line of sight and 20° to the axis of rotation. The period of rotation is 164 days. This corresponds with the parameters of motion determined by the optical evidence.

The activity in the interior of SS433 seems to be relatively uncomplicated. The velocity of the matter coming out is about a quarter of the speed of light, and it does not change from time to time, nor according to the wavelength of observation. The intensity of emission falls off as matter moves out along the corkscrew in a way that rules out some absorption mechanism operating on the radiation. The spectrum does not change with the passage of time. "The dominant thing SS433 is doing," says Hjellming, "is putting out kinetic energy."

This simple kinetic explanation may prove embarrassing for astronomers who are trying to fit the model of SS433's corkscrew jets to similar jets and tails on radio galaxies. Models of these objects generally propose some complicated physical processes in their centers to explain various aspects of their appearance. If simple kinetics can explain the jets and tails, the two pieces may prove difficult to reconcile. □

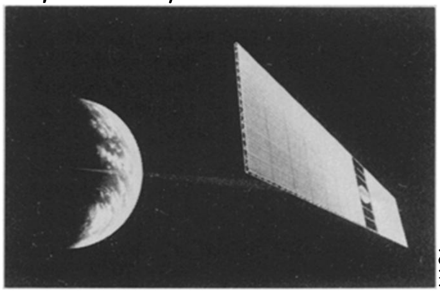
NRC opposes sunsat development funds

One proposed future answer to earth's energy problems has been solar-power satellites (SPS)—huge arrays of solar cells, miles on a side, deployed in earth-orbit and transmitting billions of watts of energy to receivers on the ground. Beside the SPS concept, involving trillions of dollars, decades of time and tens of thousands of tons of material (some of it possibly obtained from the moon and beyond), the scale of man's other major engineering endeavors would pale to near-invisibility. Yet the idea has its supporters, and calls for research into SPS possibilities prompted the National Aeronautics and Space Administration to join with the Department of Energy and several contractors last year in a detailed appraisal of what such a project might involve.

Now a committee of the National Research Council has evaluated the resultant "reference system" and concluded that no funds should be spent to "pursue development" of an SPS for at least the next decade. It could not be an economically competitive energy source in 20 years, says the committee's just-issued report, or even in twice that long a period without "radical advances in technology." The envisioned system would involve 60 satellites, each six miles long and three wide, beaming power to ground stations whose system-wide output would total 300 billion watts of electricity. The NASA/DOE study estimated that the overall cost would be about $1.3 *trillion,* and the NRC panel believes that figure to be "substantially low." A likelier number, reports the group, is about $3 trillion — roughly equivalent to an annual expenditure of 12 times the entire present NASA budget every year for the next half-century.

But even the NASA/DOE figures are mind-boggling, and there are other problems or major uncertainties virtually every step of the way. "Why, then," says the NRC analysis, "do we entertain the concept

Proposed solar-power satellite over earth.


NASA

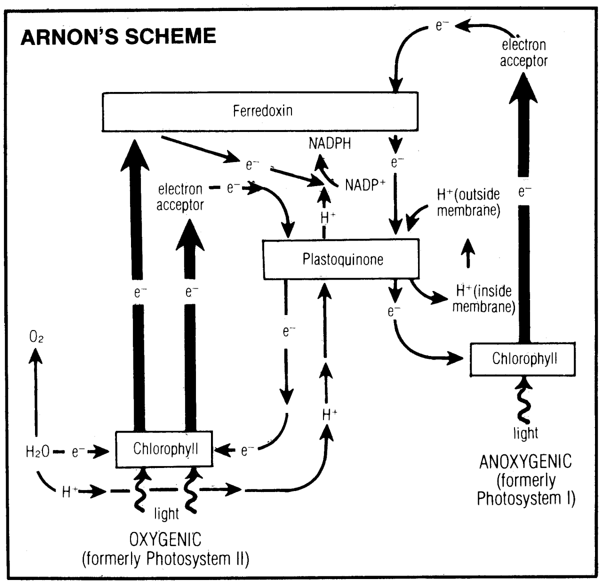
at all, let alone analyze it in the detail represented by the [reference system] with which this report is so largely concerned?" The answer is simply that circumstances could change, world energy needs escalate. Among other large-scale potential energy sources, coal raises environmental concerns, nuclear breeder reactors pose political and safety issues, fusion awaits real demonstration of its technological feasibility, and earth-based photovoltaic cells may depend on progress in large-scale electrical storage capacity if they are to ease baseload-power needs.

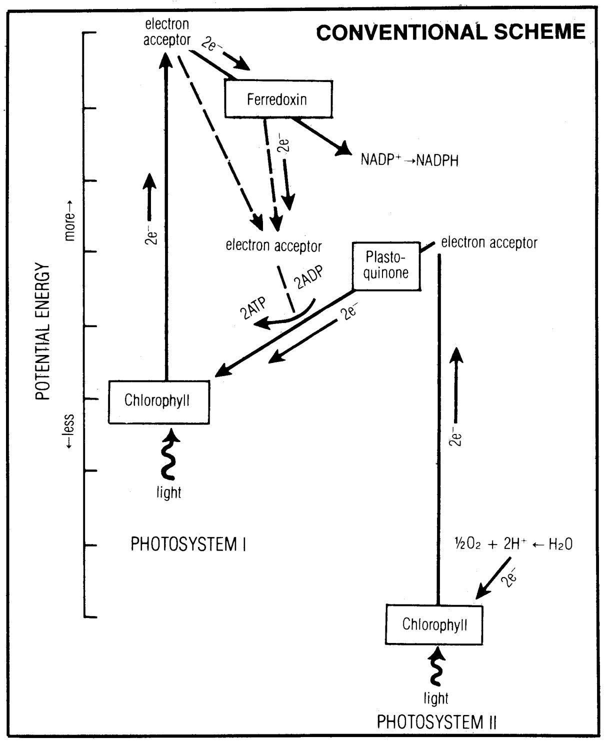
But more than in sheer dollars, the problems facing the SPS concept are largely matters of scale, such as launching vehicles with 13 times the cargo-capacity of the space shuttle more than once a day for 30 years. The sheer mass of material required to build the actual satellites has prompted advocates to propose the use of materials from the moon and possibly asteroids — a feat that, says the NRC report, "may be more difficult to achieve than building an SPS."

A side-effect of the towering costs, notes the report, is that "the size and complexity of an SPS would strain U.S. abilities to finance and manage such an enterprise and, indeed, the governmental machinery for making the decisions necessary to initiate and sustain it." In fact, the document adds, "the worldwide ramifications are so extensive that a multilateral approach with the participation of other countries would probably be the only viable one if an SPS were ever to be established." A variety of political, legal, social and military factors thus become part of the equation, potentially delving into such matters as treaties (which already constrain unilateral or commercial use of extraterrestrial materials) or even some sort of world energy authority. (Advocates of the idea have pointed out, however, that even such an inevitably global endeavor is likely to depend for its technological foothold on impetus from a country or bloc with the resources and will to take the initial steps.)

For all its misgivings, the NRC group notes that "the possibility exists that an SPS could become an interesting option at some time in the twenty-first century. . . ." Because of the multi-decade lead time such a system would require, the committee recommends that the heads of NASA and the Department of Energy (while refraining from a specific SPS research and development program) should periodically review progress in new concepts and technologies that might bear on the idea, and report them to Congress. The practicality and timeliness of any new, large-scale energy system may well depend on developments in many other fields, some of which cannot yet even be envisioned. "It is thus too early," says the report, "to attempt to pick future winners and losers." Funds for SPS are unlikely in NASA's FY 1982 budget. □

Those scheming photochemists





The New Hampshire valley-city Meriden soon will be alive with the sound of photosynthesis. Beginning July 19, researchers will gather at the Kimball Union Academy there for the Gordon Research Conference (informal but thought-provoking meetings designed to advance the frontiers of a given discipline) on the "Biochemical Aspects of Photosynthesis." At this particular conference, the precise mechanism of oxygen evolution in photosynthesis (SN: 1/19/80, p. 38), electron transfer reactions (SN: 8/2/80, p. 68) and the binding of herbicides to specific plant membranes called thylakoids probably will be favorite topics of discussion. And, as always, the work of Daniel I. Arnon and colleagues of the University of California at Berkeley is likely to stir up some debate.

Arnon has believed for some time now that there are major mistakes in the scheme most photochemists generally accept as representing the process of photosynthesis in blue-green algae and higher plants. In fact, in the June PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, Arnon presents "new evidence" to support his alternative to the conventional scheme.

Now Arnon's alternative is for the most part panned in the photosynthesis community — "He has quite a reputation for putting forth some wild schemes," says one researcher — and even his "new evidence" is "likely to fall apart," says another. Nonetheless, it *will* be discussed at Meriden. Explains photochemist James R. Bolton of the University of Western Ontario at London, "Arnon stimulates a lot of controversy, and that has its value: It forces other people to think about their [conventional] scheme."

According to the conventional scheme, two light-triggered photosystems (PS I and II) are linked together in a single pathway that uses light energy to split water. The overall photosynthetic equation is $6CO_2 + 6H_2O$ + light energy $\rightarrow C_6H_{12}O_6 + 6O_2$, but PS I and II serve only to split the water and generate NADPH and ATP — two energy-packed chemicals that in turn are used in the separate Calvin (named for Melvin Calvin of UC at Berkeley) cycle that synthesizes the "energy-storer" $C_6H_{12}O_6$, or glucose. The photosynthetic process begins at the chlorophyll center of PS II where absorbed light is used to split water into oxygen, protons (H^+) and excited electrons. The currently accepted scheme holds that these electrons travel through a series of electron acceptors, including plastoquinone. They then are passed to PS I where a second light event gives the electrons enough potential energy to be accepted by ferredoxin, which in turn passes them to NADP in order to form the "energized" NADPH. Hence, the currently prevailing concept of how photosynthetic power is generated involves a linear electron flow from water to plastoquinone to ferredoxin to $NADP^+$. The essence of this