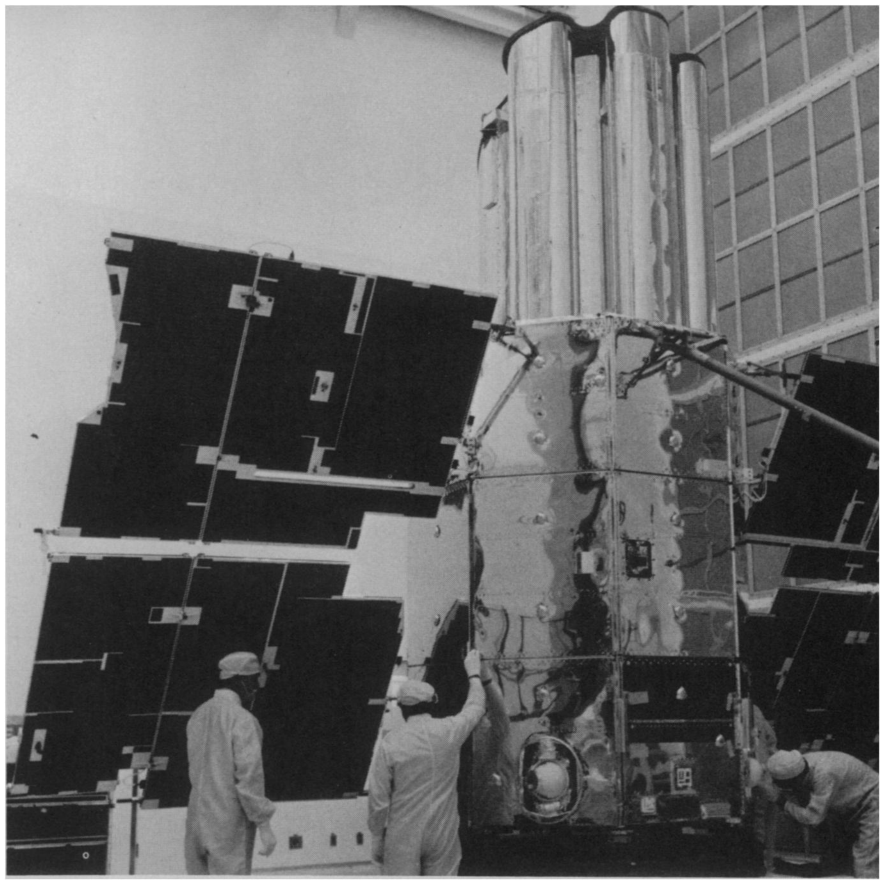
The ultraviolet and X-ray eyes of Copernicus

Interstellar gas and hot stars are main targets of the orbiting observatory



NASA

Copernicus is equipped with solar panels and a sun baffle.

by Everly Driscoll

The target is star Zeta Ophiuchi. The star finder aboard the spacecraft guides the large telescope to a specific area in the southern evening sky in constellation Ophiuchus and stops. The guidance system within the telescope then moves the spacecraft a fraction of an arc second more. It is now on target.

Although Zeta Ophiuchi, a relatively near star about 300 light-years away, is the aim, the principal region of interest is a dense interstellar cloud of gas and dust between that star and earth. One of the missions of the last orbiting astronomical observatory (OAO) is to look at the molecules and atoms between the stars. The starlight is partially dimmed by this cloud of material. By the way the dust and gas absorb part of the ultraviolet light, scientists can determine what the absorbing material is; by measuring how much of the light is removed from the spectrum, they can tell the density and amount of the particles.

This fourth observatory was named Copernicus after a successful launch Aug. 21 (SN: 8/26/72, p. 135). It carries the largest ultraviolet telescope ever orbited. The pointing accuracy approaches that required for the next generation space telescopes. It can point at an object the size of a basketball seen from 650 kilometers for periods up to one hour. The 82-centimeter telescope was provided by Princeton University. Lyman Spitzer Jr. and John E. Rogerson Jr., both of Princeton, are the principal scientists. R. L. F. Boyd of the University College of London is the principal scientist for the three small X-ray telescopes also on board. They will look at X-ray sources in wavelengths from one to 70 angstroms.

A quantum jump in knowledge about the universe has already occurred from results of the new observatory's companion, OAO 2. OAO's 1 and 3 failed (SN: 12/5/70, p. 427). OAO 2 has been working now four years. Its chief purpose has been to survey the universe in ultraviolet, collecting data for scientists to determine the content of interstellar dust and stars and thus stellar evolution. It observed light from 1,000 to 4,000 angstroms wavelength with a resolution down to 10 angstroms. The dust particles themselves, in 3,000 star fields containing 25,000 stars, were the major target. But OAO 2 also looked at 35 galaxies, two comets, six planets in the solar system, a nova and a supernova. The survey it began yielded the knowledge that scientists will now build on with Copernicus.

From OAO observations, says Nancy Roman of NASA headquarters, "we now know that the dust is not the same throughout the universe." The extinction curves—the curve that shows how the starlight is dimmed by the dust—is not the same for all stars, implying the dust is not uniform. The dust characteristics are different, for example, in areas where new stars are being formed. "There are bumps on the curves which are probably due to graphite," says Arthur Code of the University of Wisconsin, the principal scientist for OAO 2. But a combination of silicon carbides, graphite and silicates is the best model to explain the extinction curve itself.

What is the origin of the dust? "We used to think," says Code, "that the dust grains were manufactured in interstellar gas and that the grains were dirty ice." Astronomers now think water ice cannot be a significant part of the composition of these grains, even though the comets turned out to be largely water ice. The dust grains are probably being formed in the outer atmospheres of the stars. The stars themselves could be made from the accretion of such particles. If so, says Code, citing a Biblical verse, "it is indeed from dust to dust. . . ." While OAO 2 obtained a coarse resolution of the interstellar dust, Copernicus will look at the interstellar gas with 100 to 200 times better resolution than OAO 2 (from 1/20 to 1/10 angstrom).

"We think there is a relationship between the dust and gas," says James E. Kupperian Jr. of the Goddard Space Flight Center. Carbon stars emit carbon vapor. The carbon cools and condenses into small grains of graphite. The same could be true for other metal-rich stars.

The most common element in the universe and in the interstellar gas is hydrogen. Neutral atomic hydrogen absorbs the Lyman alpha wavelength

(1,216 angstroms) very strongly as starlight passes through it, and it is on this line that a good deal of ultraviolet astronomy has concentrated. OAO 2 was able to observe this line in the spectra of 70 young stars (spectral type B2 or earlier). In later stars the stellar emission of the Lyman alpha is too strong to allow useful measurements of the interstellar absorption. Nevertheless the new data are sufficient to permit investigation of relationships between the amount of neutral hydrogen (determined from the absorption) and other interstellar matter (atoms, molecules and grains) over precisely the same path. Radio investigations of these matters have been done, but they usually average the brightness over a wide angle (usually about one degree), and the path length for radio emission is often uncertain.

While earlier studies had yielded values of one to one-tenth atoms of hydrogen per cubic centimeter, OAO returns reveal that between earth and the bright stars in the constellation Orion, as well as along the path to other near-earth stars, the values are more like one-fifth atoms of hydrogen per cubic centimeter. For stars with an average distance from earth of about 1,000 light-years, there are about three-fifths atoms of hydrogen per cubic centimeter. The new OAO will allow scientists to determine the density and distribution of molecular as well as atomic hydrogen.

Some variable stars, such as A-type stars, show an overabundance of certain rare-earth and iron-peak elements. In the spectra of these stars there appear variations from time to time of the intensities of the lines due to these elements and in the velocities deduced from the redshifts of the lines, which indicate how fast the materials in question are moving. The usual explanation of these variations has been that patches in which these elements are concentrated rotate with the star and cause the changes as they move across the line of sight.

The OAO 2 light curves for alpha (2) Canum Venaticorum indicate that when the intensity of the rare-earth lines is at a maximum, the continuum ultraviolet radiation short of 2,900 angstroms is greatly diminished while the visible range of the spectrum becomes brighter. "We used to think this was due to temperature changes," says Roman. Now scientists believe the cause is strong absorption of certain lines in the ultraviolet range by elements in the outer atmosphere of the star (possibly the same rare-earth elements), called line blanketing. The energy thus absorbed in the outer atmosphere is thrown back into the star, but sooner or later it must come out, and when it does, it comes out as visible light, brightening the visible spectrum. "In the case of this star," says Code, "we can't be sure the blanketing is due to the rare-earth lines or not." With Copernicus, scientists will be able to resolve the individual lines and study the amount of absorption at each wavelength and thus determine responsibility for the blanketing.

Another peculiar star OAO studied is Beta Lyrae. One component of this eclipsing binary system is a hot B-type star. Scientists know that the two stars exchange part of their mass. This process produces a large number of emission lines in the ultraviolet. "But," says Roman, "while we see the effects of the gravitational attraction we don't see the spectrum of the companion star of Beta Lyrae." This has led some scientists to speculate that the companion of the hot star is a black hole—a star that has collapsed because of its own gravitational force. (The force is so strong that no light is emitted.) "Whatever represents its [Beta Lyrae's] companion isn't like any star that we know," says Code.

Copernicus will concentrate on young hot stars. Initially it will look at 47 such stars in the Milky Way galaxy. Most of these stars have stellar hurricanes, or shells of gas and material coming off. Kupperian thinks that the stars are rejuvenating themselves in this way—the heavy matter is thrown back into space where it accretes to form more stars. OAO 2 found that these stars were the answer to one puzzle. The telescope observed the globular clusters—compact old clusters of stars that have a spherical distribution around the galaxy. But when astronomers added up the light and then counted the stars, it didn't come out right. There was too much light for the number of stars there. "The hot blue stars were the answer," says Code. There had been theories of their existence, but no one had seen them. The hot stars OAO 2 found behave much the way the theories had predicted they would, except that in some cases they are hotter.

The last OAO, launched last week, will look at molecules and atoms between the stars

Data from OAO 2 also indicated that the intensity of radiation in nebulas in other galaxies increases in the far ultraviolet. Some of this excess energy could also be attributed to the hot stars. But the rise of intensity was too steep to be attributed to the stars alone. One theory for the excess energy is that dust within the galaxies reshapes the energy curve.

Nova Serpentis occurred in February 1970. OAO 2 observed it for 60 days. Then in May 1972, one of the brightest supernovas in 35 years occurred in galaxy NGC 5253. OAO watched it for 16 days.

Both novas and supernovas are stellar explosions, but they differ in intensity and in their effects on the involved star. During the first couple of months after the Serpentis outburst, the visual light decreased, but the ultraviolet increased. One explanation for this is that the nova threw out an envelope of gas that didn't disturb the star. The shell, or envelope, absorbed the radiation and then reemitted it as visual light. As the shell expanded, it became thin enough for some ultraviolet light to get through. "We used to think a lot of energy came out of a nova and then dropped off," says Code. From the new data, astrophysicists now know that there is very little change in the total amount of energy radiated. Instead, the energy moves from the ultraviolet to the visible and back again to the ultraviolet.

The supernova, in contrast, had visual and ultraviolet light emissions of about the same intensity (although the UV was a little brighter). It was a catastrophic event. Material was emitted at velocities of 2,000 to 3,000 kilometers per second. Not much of the star was left after the explosion. Probably what was left was a neutron star. The supernova shell was not as opaque as that of the nova's, and it didn't bottle up any radiation, thus the visual radiation was the same intensity as the UV.

Before OAO observed the supernova, astrophysicists thought that the light seen was connected to the release of energy from thermonuclear reaction and that the visual light curve represented the decay of the radioactive elements. If this had been true, the rate of decay would have been the same at all wavelengths. That didn't happen. Astronomers now conclude that the light seen represents the expanding and cooling of gas from the explosion rather than radioactive decay.

The X-ray telescopes on Copernicus will study in detail some of the sources discovered by Uhuru, the X-ray satellite (SN: 6/10/72, p. 382).

Neither OAO 2 nor Copernicus are able to see quasars—objects that are moving away at high velocities and emit more energy than that emitted by most galaxies. The puzzle of quasars will have to await the next generation space observatories. But more than likely, if Copernicus continues to work, it will uncover more mysteries of the universe—some that exist in theory, and some that no one has thought of. □