ASTRONOMY

Study "Empty" Space

Far From Complete Vacuum, It Holds Cosmic Clouds Of Enormous Size and Inconceivably Low Density

HALF the Milky Way, it has been estimated, is "dust."

The great stellar system of which the sun and its planets is a part contains billions of stars. They are so thinly distributed that light, traveling at approximately 186,000 miles a second, takes six or seven years to go from one to another.

Until a few years ago it was assumed that these vast spaces were empty. They are, according to any common terrestrial idea of emptiness. The most complete vacuum attainable on earth would be extremely dense in comparison with the state of matter in the great interstellar interstices.

But when compared with an ideal vacuum, these enormous, atmosphereless stretches of nearly absolute cold are actually full of gas and dust. Highly tentative values for the density of matter in space, calculated a few years ago by astronomers of the Carnegie Institution of Washington, are, for each cubic meter, six sodium atoms, two-tenths of a potassium atom, one-tenth of a calcium atom, and a thousandth of an atom of the relatively rare element titanium, in addition to very much larger numbers of hydrogen atoms and of free electrons. Now there must be added a minute bit of iron and various very simple carbon molecules.

Not Equally Distributed

This matter is not distributed equally through space. It is gathered in cosmic clouds, often of enormous size and of inconceivably low density. In some parts of the heavens these clouds are so extensive and numerous that they affect profoundly the light from far-away stars passing through them, shut off from view distant parts of the galaxy, and tend to give astronomers a distorted picture of the system. For one thing, they make it seem larger than it actually is. Their distribution, size and composition constitute a major problem of present-day astronomy.

Just as a dust cloud on the surface of the earth dims and reddens sunlight which passes through it, so these cosmic clouds reduce and redden the light which comes from stars lying beyond them. This reddening is due to the fact that blue and violet light is scattered and absorbed to a much greater extent by dust and gas than is red light. However, by utilizing the superior penetrating power of red light with red-sensitive photographic plates, it has been found possible to extend observations far more deeply than ever before into the complex structure of star clouds and masses of gas concentrated in various regions of space.

One such cloud reddens appreciably the brighter stars in the vicinity of the North Pole. It has a thickness of about 1,000 light years and its nearer edge is some 200 light years distant from the earth. Cosmic clouds are especially abundant in the neighborhood of the Milky Way and prevent astronomers from observing the center of the galaxy, which lies in the direction of the constellation of Sagittarius in the southern sky.

Redness Shows Size

By means of the reddening of light astronomers can estimate the size and density of such clouds. This tells nothing of the nature of the matter composing them. Such information must be obtained in another way—extremely difficult but recently highly productive. Astronomers can actually count the atoms in space, or at least make fair estimates of the number of primary particles of various elements and their physical states.

One of the major accomplishments of modern physics has been the development of spectroscopy.

Each of the 92 chemical elements, when rendered luminous, has a unique spectrum. As an illustration, if the metal calcium is vaporized in an electric arc the resulting gas gives out a definite pattern of bright spectral lines characteristic of calcium and calcium alone. Radiation of quite different wave lengths is given out by luminous iron. Throughout the entire table of the elements not a single pattern is duplicated. When a physicist detects a certain light pattern anywhere in creation, he knows that its source is one specific element only—that where he finds a pattern of the copper spectrum there must be copper, whether it be in a drop of blood or in a star.

Most of the elements have extremely complex spectra consisting of thousands of wave lengths extending from the invisible infrared through visible light far into the invisible ultraviolet. Different lines appear according to the state of the atom—whether it has all its outer electrons or whether one or more of these have been stripped away. Still other lines appear when the element is in molcular combination with some other element.

Physicists have found and classified nearly all the spectral lines of all the elements in their neutral states, in their singly and doubly ionized states, and in their simpler combinations. The labor involved has been almost unimaginably vast. It makes possible analysis of the content—that is, the gas content—of the cosmic clouds.

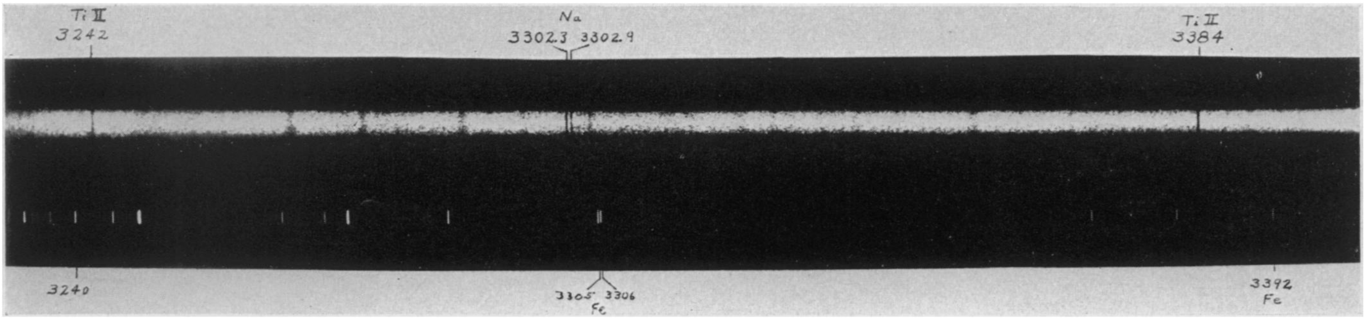
It has long been known that some of the light which passes through a gas is absorbed by the atoms and molecules of the elements which compose the gas. An atom will absorb, however, only wave lengths which, if luminous, it would itself emit. An atom of copper can capture only "copper light," and an atom of phosphorus only "phosphorus light."

The result is a narrow black line on a spectrum photograph. When such lines appear in the spectrum of the light of a star it can only mean that this light has passed through a cloud of atoms of the element which could itself give out the corresponding wave lengths. If a cloud of calcium atoms is present in space, under suitable conditions some of these atoms can absorb the same lines which they can emit in the laboratory.

Spectral Lines Are Faint

Most of the spectral lines of most elements are extremely faint. It must be considered that under the extraordinary conditions of temperature and density which exist in interstellar space, only the very few lines which arise from normally undisturbed atoms can appear, and these will be very dim. The intensity of the lines depends on the number of atoms in a state suitable to absorb light of just the proper frequency of vibration. These, in a gas of extremely low density, are certain to be few.

About 40 years ago came the first clue to the composition of space gas. A German astronomer discovered two faint, narrow lines in the spectrum of a star



SPECTROGRAPH FROM SPACE

It is this sort of record that has revealed to scientists the make-up of the great clouds in heavenly space. On the broad white line, the dark bands near each end indicate the presence of ionized titanium. The close pair in the center are due to neutral sodium.

in the constellation of Orion which were completely different in character from the stellar lines and showed motion —which also can be determined from the nature of the spectrum—quite distinct from that of the star.

They soon were recognized as due to atoms of ionized calcium, that is, atoms minus one electron. Several years later the existence of normal sodium was established from the presence of two well-known lines in the orange region of the spectrum. It so happens that both these lines are easily produced and are exceedingly prominent in laboratory sources and in the spectrum of the sun.

Needed Powerful Equipment

The next step awaited the development of more powerful instrumental equipment. Then, about four years ago, astronomers of the Mount Wilson Observatory identified four lines as due to ionized atoms of the rare element titanium and one each of neutral calcium and neutral potassium.

At the same time they found various other faint lines which were hard to match. Nine of them were in the blue and violet portion of the spectrum. The lines were sharp and narrow in appearance. Seven others, mostly in the red region, were diffuse and broad. The origin of these latter is still unsolved. The blue and violet lines did not correspond to any known to come from any of the elements. The suggestion that they might be due to molecules came from several independent sources. A detailed investigation was made at the Dominion Astrophysical Observatory in Canada. It was concentrated on the relatively few lines, out of the thousands in the bands of the more common compounds in the laboratory, which might be expected to occur under the conditions of interstellar space. Among these were a few lines of the simplest carbon combinations — carbon - nitrogen and carbon-hydrogen. Such a molecule consists of one atom of each element.

Six of the blue and violet lines in interstellar clouds matched lines of these compounds. Three others, two fairly prominent in the clouds, remained unidentified. Within the past few months investigations at the University of Saskatchewan have shown that these also belong to carbon-hydrogen in an ionized condition, or with one electron missing from one of its atoms.

The latest discovery of the Mount Wilson astronomers is that of iron in interstellar space. This is an abundant element throughout the universe. The light given out by iron atoms, however, is distributed among the great number of spectral lines and none is of such predominant intensity as that of some of the lines of calcium and sodium. Any interstellar iron lines could be expected to be extremely faint.

The search was concentrated on two ultraviolet lines in the iron spectrum which arise from the undisturbed state of the atom. After repeated attempts these have been successfully photographed.

At Interesting Stage

The study of these cosmic clouds now is at a most interesting stage. Astronomers know, in part, what they are made of, although doubtless other elements and other simple molecules will be found. They know something of their size, density and distribution. Their composition is far from uniform. Different elements appear to predominate in the gaseous composition of different clouds. This is a field which calls for detailed investigation.

The clouds are not stationary. They are moving with all the complex movements of the galaxy and they have independent drifts of their own. The direction and rate of their movements also can be deduced from study of their spectra. There is a shift towards the red end of the spectrum when an object is moving away from an observer, and the extent of this shift depends upon the speed. Conversely, there is a shift towards the blue when an object is approaching. The motions of the clouds with respect to one another now are being studied. From these investigations may come new light on complex dynamics of the titanic star system.

Interstellar space provides a laboratory for the study of matter under conditions which can be found nowhere else. What is the state of matter under such conditions? Study of the clouds between the stars holds out a hope for some of the answers.

With techniques known at present there would appear to be no hope of penetrating beyond some of the densest of these clouds. They are like great black curtains drawn down in the face of man's curiosity regarding some of the remotest and most significant regions of the vast system of which he forms a part, such as the center of the galaxy. The more he can learn about the nature of these curtains, the greater the prospect will be of seeing something of the mysteries which they hide.

Science News Letter, November 1, 1941

RESOURCES

Midwest Now Grows Coriander Seed

CORIANDER seed that add pungent flavor to candy, beverages, soup and other products are now coming from midwestern farms, instead of such far-off lands as Morocco, France, and the Balkans.

Present midwestern planting consists of 150 acres, with production of about 40,000 pounds of seed. Coriander was formerly summed up by the Department of Agriculture: "No commercial production in the United States."

Science News Letter, November 1, 1941