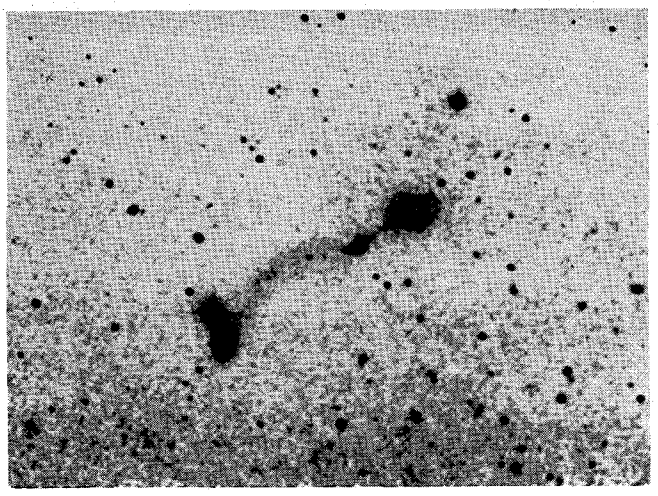


This photograph from the 48-inch Schmidt telescope (enlarged 17 times) reveals how some extragalactic nebulae are connected. The three black objects in the center of the picture are galaxies like our Milky Way. A band of luminous matter runs between them like a lighted, gently curving boulevard.

BRIDGES IN SPACE

By ROBERT G. FIEDLER

ASTRONOMICAL RESEARCH at the Institute has shown that some widely-separated extragalactic nebulae do not necessarily live in complete isolation from each other. Luminous bridges more than ten thousand million million miles long—substantially longer than any previously known—have been found to extend between a number of these gigantic starry islands which float by the millions in the universal ocean of space.

These observations were made by Dr. Fritz Zwicky, Professor of Astrophysics, and have been confirmed with various instruments at Caltech's Palomar Observatory and the Mount Wilson Observatory of the Carnegie Institution of Washington.

When men first started asking questions of the stars, the universe they knew was relatively small. In the time of Galileo that universe embraced a few thousand naked-eye stars plus the planetary system—the sun and its attendants: Earth, Mars, Venus, Jupiter, etc.

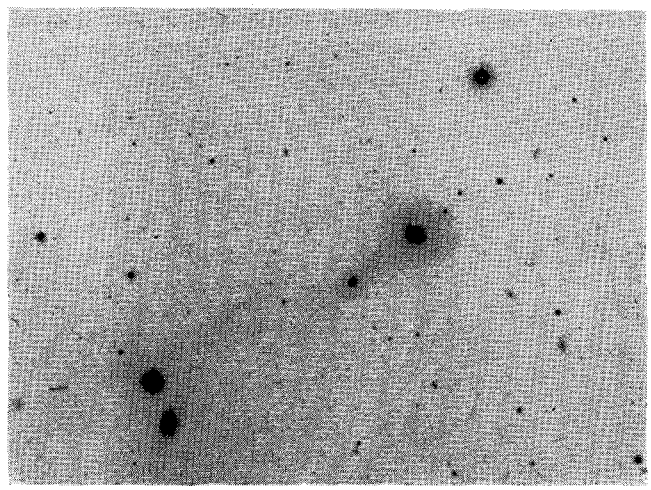
As man grew older and wiser, so did his insignificance as an occupant of the universal ocean grow—but so, too, did his vistas and the scope of possible new worlds to conquer. Life became more exciting for those men who liked to gaze at the stars and ponder the questions the stars themselves posed, when they realized that their planetary system was only a small part of that hazy, star-peppered streak in the sky which they knew as the Milky Way or the Galaxy.

And then, in our own generation, man's place in the universe shrank again as he devised more powerful instruments to probe the obscure depths, and put these instruments into the skilled hands of men with disciplined minds to do with as they willed. So, inevitably, man became more insignificant still in the large scheme of things, but now his eye and his mind could range over an almost incomprehensible sweep.

For Dr. Edwin P. Hubble of the Mount Wilson Observatory discovered that some of the fuzzy bright spots astronomers had been looking at were not the dust-and-gas clouds they had thought, but actually were composed of stars. This meant they were agglomerations like our own system, the Galaxy—bustling with the same sort of activity, inhabited at least by stars, and probably also by counterparts of objects residing in the Milky Way: dust, gas, star clusters, etc. He called them extragalactic nebulae* and found they were at distances which have come to be known as "astronomical."

*Some astronomers call these vast stellar systems "galaxies," since they resemble the system of the Milky Way. Others prefer to maintain the traditional definition of "Galaxy": the Milky Way; and to call the systems outside it "extragalactic nebulae." The latter, however, should not be confused with "nebulae" in the Milky Way, which are nebulosities or clouds of gas and dust. All nebulae discussed in this article are extragalactic.

This photograph from the 200-inch Hale telescope shows the same system pictured in the 48-inch plate across the page. The bridge joining the objects is still apparent, though this picture is enlarged only 3½ times. The internebular bridge, incidentally, is more than 72,000 light years long.



Astronomical research at Caltech reveals that a number of widely-separated extragalactic nebulae are actually connected by luminous bridges in the sky.

So remote are these nebulae that the mile becomes almost as minuscule as its inventor, and astronomers talk of their separation from us in terms of light years. One light year is roughly six million million miles, the distance light travels in one year at 186,000 miles each second.

After the identification of extragalactic nebulae, astronomers found that luminous filaments sometimes join comparatively close double nebulae, like the bars of dumbbells. But it had not been generally known that faint luminous clouds stretching between nebulae separated by extremely great distances—many times the diameters of the nebulae involved—are relatively common. Professor Zwicky found such internebular highways in plates exposed with the 18-inch Schmidt telescope on Palomar Mountain and later with the 48-inch Schmidt, which—like the 200-inch Hale telescope—has proved capable of recording fainter objects than had hitherto been possible. The phenomenon is illustrated in the following example (one of the first encountered):

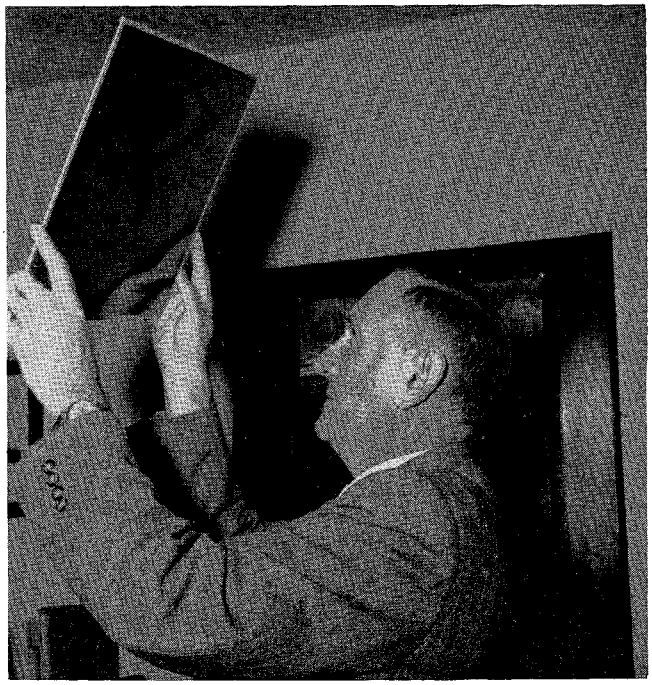
The system in question (see page 20) consists of three nebulae in the constellation of Virgo at a distance of about 50 million light years from the earth. Between the nebula (IC3481) at the upper right and the one (uncatalogued) immediately below and left of it lies a band of luminosity almost as sharply delineated as a lighted boulevard. Between the anonymous nebula and the one (IC3483) at lower left arches a somewhat less sharply defined strand shaped like an oriental sword. On the present distance scale IC3481 and IC3483 are separated by a projected distance of 72,000 light years. Thus the internebular cloud, because of its yataghan-like course, has a span greater than 72,000 light years.

The photograph from the 48-inch, largest of the Schmidt-type instruments, was enlarged 17 times from the original plate and its contrasts enormously enhanced by repeated alternate printing on contrast plates. On the original plate the contrast between the cloud and the sky background is so slight that a casual observer might easily miss it. Professor Zwicky notes, however, that once the observer knows what to look for, a discerning eye can readily detect many similar cases. The most important of the systems so far spotted are now being photographed with the 200-inch telescope.

What are the constituents of the lane between IC3481 and IC3483? Red- and blue-sensitive plates from the 48-inch Schmidt and the Mount Wilson 100-inch telescope seem to indicate that the cloud is relatively blue although many shades of color exist. This may mean that the material differs in composition from one region to another, and one possible explanation is that there are different relative numbers of blue and red stars in it. It has not yet, however, been resolved into stars.

It is possible only to make a guess as to how this

Dr. Fritz Zwicky, Professor of Astrophysics at Caltech, examines a plate from the 48-inch telescope to confirm his recent findings on internebular bridges.



lane came to be. One tentative explanation would run like this: The three nebulae may be rotating around, oscillating through, or passing each other. When they are at their closest approach they disrupt one another. They may then eject stars and perhaps other matter into the space around them. It may even be that some stars are escaping from the triple system entirely and hurtling into the space outside the cloud.

Another conceivable explanation might be that some of the internebular cloud, or perhaps even most of it, may have been formed when the nebulae were born or may have originated independently of them.

Whether such bridges are numerous enough to mean that the amount of matter in the universe has been underestimated by a significant amount is a question for the future. If they prevail widely, and if, in addition, dust is demonstrably present in internebular space (and Professor Zwicky believes he is accumulating evidence to this effect), then some revision may be indicated in such estimates and also in those portions of cosmological theories influenced by them.

The amount of matter in the universe, its distribution and the average density of the universe are all basic to cosmological theory. If one root factor changes appreciably, the effect is felt in all branches of the structure growing from it. Knowledge of the masses of the nebulae themselves is important to cosmologists, and one method of determining these masses is by calculation from appropriate measurements on *double* nebulae. However, it is not always irrevocably certain that two nebulae are true doubles when they are observable only in the line-of-sight. They might be several hundred thousand light years apart and the accuracy of the reckoning may suffer for this reason. But nebulae bridged by filaments such as Professor Zwicky has found are definitely double, triple or otherwise multiple systems with all their members at very nearly the same distance from the observer.

The discovery also has implications in the estimation of the distances of far-off objects. Astronomers cannot rule off or step off the distance to nebulae, and have had to resort to a roundabout method. This method depends on the absolute brightness of the object whose light they capture on photographic plates or in electronic instruments. Light, passing through a fog, is fainter on the other side of the pall than if it traveled through a vacuum. Thus, if dense internebular clouds should abound in space they might absorb enough of the light from distant nebulae to produce errors in the estimation of nebular distances.

One interesting sidelight is a possibility that the Milky Way itself may be joined to our 90,000-light-years-distant neighbor, the Nubecula Major or Large Magellanic Cloud. More than a century ago the British astronomer, Sir John F. W. Herschel, wondered about this as, "entirely without telescopic aid, when seated at a table in the open air, in the absence of the moon," he scanned the southern skies from a South African observatory at the Cape of Good Hope. He wrote that no branch of the Milky Way whatsoever forms "any certain and conspicuous junction with (the Nubecula Major); though on very clear nights I have sometimes fancied a feeble extension of the nearer portion of the Milky Way in Argo (where it is not above 15° or 20° distinct) in the direction of the nubecula."

Professor Zwicky has called this observation, and his own findings on internebular bridges, to the attention of the Commonwealth Observatory at Mount Stromlo, Australia. Astronomers there have replied that they will be on the lookout for any connection with the Large Magellanic Cloud, which is visible only in the southern hemisphere.