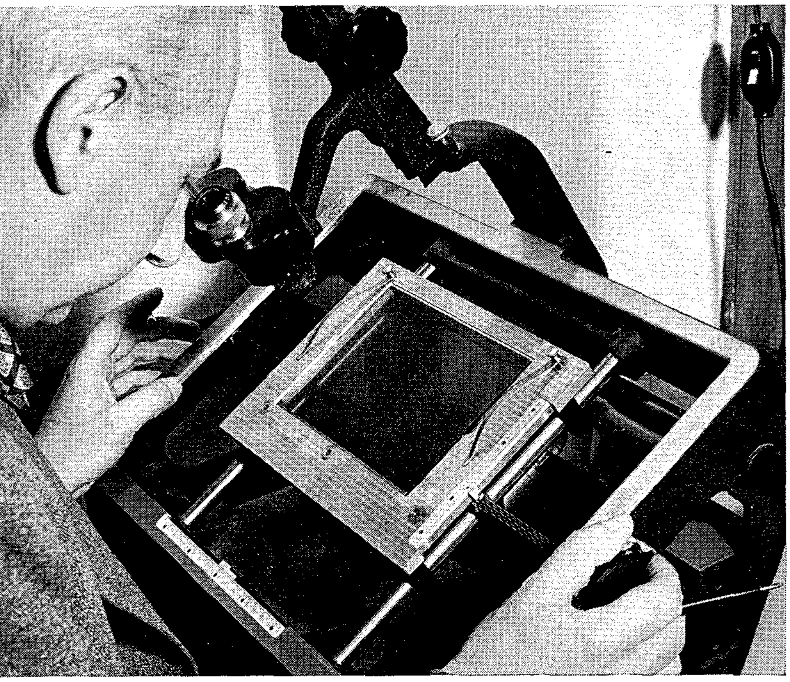
light—the spectrum is continuous and each color blends into the next, starting with red at one end and continuing through orange, yellow, green and blue to violet at the other end.

However, if the light source is a glowing gas—gas such as that used in a neon sign for example—the spectrum is broken up into a series of bright disconnected lines. In some instances, such as light from a filament shining through a gas, the same lines appear as black ones cutting across the continuous colors of the incandescent light.

The arrangement and number of these lines, regardless of whether they are dark or bright, are determined by the gaseous chemical elements in the source. Helium has one characteristic group of lines, hydrogen another, vaporized iron another, etc. Thus it is possible to determine accurately by spectroscopic analysis the presence of elements in a star source.



Dr. Walter Baade of the Mount Wilson Observatory examining a plate with a comparator. Photograph by E. R. Hoge.

Also, the brighter the line the greater the amount of this element, so by measurement of brightness and characteristic groups of lines, both the element and its quantity can be determined.

By comparing the relative brightness of red and blue parts of the spectrum, the astronomer can determine the temperature of the star. He can also determine the velocity at which the star is moving by comparing the shift in spectrum lines with those of the same element in the laboratory. So too, he can determine the pressure in the source star by studies of intensities of lines.

Thus, by all these means, the astronomer can learn a great deal about the makeup, size, distance, temperature and pressure of a star millions of light years away (a light year is the distance light, traveling at 186,000 miles per second, goes in one year).

In obtaining spectrum information, the astronomer uses a spectrograph. Here too he takes photographs and does not observe visually. Spectroscopic exposures may require an entire night, or even more than one night.

After photographs have been obtained, the astronomer returns to Pasadena and begins his laboratory analysis of what he has secured. These laboratories are equipped with many precision instruments designed to measure astronomical data obtained photographically. There are comparators which can measure the position of a star image or a spectrum line with an accuracy of a few thousandths of an inch. There are microphotometers for measuring the blackening of photographic images quantitatively to determine the brightness of the star or the strength of the spectrum line. This information can in turn be used to calculate the distance of the star or the amount of any given chemical element it may contain.

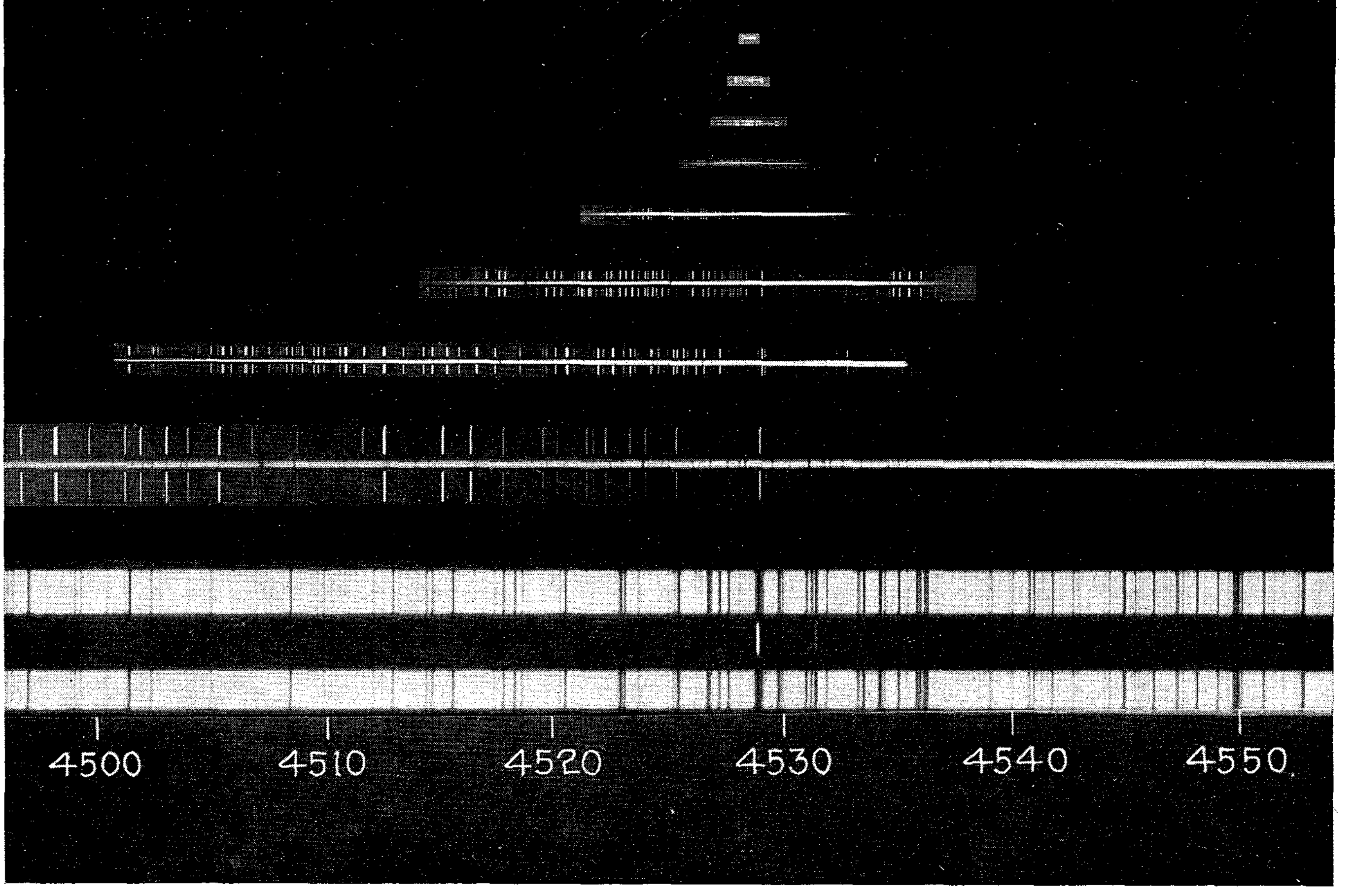
It may often take weeks, or even months of work in the laboratory to measure and interpret information obtained on photographic plates in a single night. Thus, between the time an observation is made and the determination of complete information about that particular photograph, there may be a lag of months. It is for such reasons that knowledge of new information about the universe obtained by the 200-inch telescope may not be announced for a year, perhaps years, after such data was actually recorded on a photographic plate.

PHOTOGRAPHING THE STARS

TODAY'S astronomer observes a photographic plate. In large observatories the visual observer has all but disappeared. At Mt. Wilson, in all of the solar and stellar records that are made, the only visual observations now taken are a drawing of the sun and a record of the magnetic field strength of sun spots. Except for the possible examination of a comet, it is very improbable that an astronomer at a large observatory will look through a telescope.

The many photographs exposed at an observatory are used not only for immediate scrutiny, but also for future reference. Of the over 50,000 taken since the Mt. Wilson Observatory commenced operation, a great number have been filed after only a cursory study. While stars that have been recorded by the 100-inch Hooker telescope may be traveling at a rate perhaps one-quarter the speed of light, the distances involved are so great that a wait of many years, perhaps 20 to 50, will be necessary before a shift can be measured. It is with this future comparison in mind that so many photographs have been taken.

Another of the advantages of photography is the accumulative property of photographic emulsions. A five-minute exposure will show all of the stars that



A display of stellar spectra taken with increasing dispersion from 835 Angstroms per mm to 0.7 Angstroms per mm. The spectra shown above are photographic prints or "positives". Actually the astronomer works almost exclusively with the original plate or "negative" as a matter of convenience.

can be seen with the naked eye. Some direct photographs are taken with exposures of several hours. And in spectroscopic work, analyzing light from the stars, cumulative exposures of 50 to 60 hours, taken on several successive nights, are not uncommon.

Once made, the photograph is there for all to see. Some of the drawbacks of visual observation are shown in the current controversy over the surface of the planet Mars, which may be cleared up with the use of the 200-inch Hale telescope. The surface of Mars has proved very difficult to photograph, owing to an enveloping atmosphere of carbon dioxide. Visual observers have varied considerably in their reports of observations of the red planet. Acceptance of the "canals" is by no means universal. It is for this reason that instantaneous photographs or "snapshots" of Mars, which may be possible with the great light-gathering properties of the 200-inch, will probably be included in its research program.

There are two main types of records made, direct photographs and spectrographic photographs. The direct observations show planets, stars and star clusters from our own galaxy, and extra-galactic or "spiral" nebulae, which are complete solar systems resembling our own. Spectrograms, analyzing light from the stars, give their chemical composition, velocities through space, and their distances from each other and from the earth. For physicists there is much to be learned from spectrograms, for the examinations of the universe show the same chemical elements that are present on the earth, but acted upon by conditions of pressure and temperature difficult to duplicate in the laboratory. Nevertheless, attempts are being made. There are fields of astronomy in which workers try to duplicate solar and stellar spectrograms by laboratory methods, gaining considerable insight into the conditions producing such a record.

For spectroscopic work, photographic plates from 8x10 inches in size down to as small as ¼ x1 inch are used, depending on how widely the light from a distant star can be spread out with a dispersion grating. A dispersion grating is a series of tiny scratches on a metal plate which, if sufficiently parallel and close enough together, will break up a beam of sunlight in much the same way as a prism, but with considerably greater dispersion.

Very important in the development of photography as an aid to astronomy has been the research work on emulsions by the Eastman Kodak Company and other firms. By perfecting plates sensitive to light over the whole range of the spectrum, especially red, photographic research has opened new vistas to spectroscopy. Responsible for much of this work is Dr. C. E. K. Mees, research director of Eastman, who told Dr. Hale: "If you build large telescopes, I'll make them larger yet with better plates!"

As far as direct photographs are concerned, those now taken at Mt. Wilson are of comparatively short exposure. Exposures of over a few hours are fogged by the lights of the San Gabriel Valley and nearby Los Angeles. The Palomar Mountain location of the Hale telescope will give astronomers black night in which to work.

Coming in the recording of light is research with the photo-electric cell. By expressing light as an electric current, the study of stars of variable magnitudes will be intensified. Hitherto it has been necessary to take countless photographs of a variable star and compare them, making necessary allowances for variations in "seeing". With the photo cell, a continous record may be kept, showing conclusively the variations and their rates of change.