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MT. WILSON, CALIFORNIA
NO. 3.

A PROGRAM OF SOLAR RESEARCH

BY
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A PROGRAM OF SOLAR RESEARCH[1]

By GEORGE E. HALE

In an article on "Solar Research at the Yerkes Observatory"[2] I have given, in outline, a program of solar investigations prepared several years ago. Some of the investigations included in this program were carried out at the Yerkes Observatory, and others are still in progress there. As explained in another paper,[3] it was found that the solar spectrograph attached to the 40-inch telescope was of insufficient focal length for satisfactory photographic work on the spectra of sun-spots, and accordingly this work was postponed, and has recently been taken up at the Solar Observatory. For similar reasons it was found to be advantageous to delay other investigations until the completion of the Snow telescope. We are finally in a position, however, to attack the whole question seriously. I have therefore thought it might be of interest to publish the revised program of solar research which we are putting into operation on Mount Wilson.

In preparing this program, two principal purposes have been considered: (1) the study of the Sun as a typical star, with special reference to stellar evolution; (2) the study of the Sun as the central body of the solar system, with special reference to the relationship between solar and terrestrial phenomena.

The proposed investigations include:

I. DIRECT PHOTOGRAPHY

a) Daily photographs of the Sun on a scale of 6.7 inches (17 cm) to the diameter, for comparison with spectroheliograph plates.

b) Large-scale photographs of spots and other regions, for the study of details.

II. PHOTOGRAPHIC STUDIES OF THE SOLAR ATMOSPHERE WITH THE SPECTROHELIOGRAPH

a) Daily photographs of the Sun with the lines:

[1] *Contributions from the Solar Observatory*, No. 3.

[2] *Astrophysical Journal*, 16, 211, 1902.

[3] *Contributions from the Solar Observatory*, No. 5: "Photographic Observations of the Spectra of Sun-Spots."

(1) H_1, showing the calcium flocculi at low level.
(2) H_2, showing the calcium flocculi at higher level.
(3) H_2, showing the calcium flocculi at higher level and the prominences (composite photographs, with separate exposures for flocculi and prominences).
(4) $H\delta$, showing the hydrogen flocculi.
(5) Other dark lines, as may prove feasible, showing the flocculi of the corresponding elements.[1]

b) Measurement and discussion of the above photographs, involving:
(1) Determination of the area of the flocculi and their distribution in heliographic latitude and longitude. These results will give a measure of the relative activity of different elements in various regions of the solar surface; furnish the means of answering certain questions regarding the relationship of flocculi to spots, such as the time of first appearance, relative position on the disk, etc.; and serve for comparison with meteorological and magnetic records.
(2) Measurement of the heliocentric position of points in the flocculi that can be identified on several successive photographs, to determine the law of the solar rotation for the corresponding elements.
(3) Determination of the position, area, and brightness of eruptive phenomena, to find whether they are related to other phenomena of flocculi or spots, to possible changes in the absorption of the solar atmosphere, and to auroras and magnetic storms.
(4) Measurement of the area and brightness of the neutral or bright regions near sun-spots, on photographs of the hydrogen flocculi, for comparison with other phenomena, such as the velocity of ascending and descending currents of calcium vapor, the intensity of radiation (for given wave-lengths) of the spots and neighboring regions, etc.
(5) Study of the motion of the high-level calcium vapor, especially in flocculi overhanging sun-spots, to determine the direction and velocity of horizontal currents.
(6) Measurement of the position and area of prominences, and study of their relationship to solar and terrestrial phenomena.

[1] λ 4045, showing the iron flocculi, is now used daily.

c) Special studies with spectroheliographs of suitable dispersion, involving the use of various dark lines (including enhanced lines) and of lines affected in spots; simultaneous photographs of eruptions on the disk in different lines; comparative studies of quiescent and eruptive prominences with the hydrogen and calcium lines, etc.

III. SPECTROSCOPIC INVESTIGATIONS

a) Daily photographs of the spectra of spots, region $H\alpha$ to $H\beta$, for the determination of intensities and the identification of lines that are widened or otherwise affected.[1]

b) Photographs of the H (or K) line, with high dispersion, on successive sections of the disk, to give the radial velocity of the calcium vapor in the flocculi, chromosphere, and prominences.

c) Measurements with the bolometer of the relative radiation, corresponding to various wave-lengths, of the sun-spots, faculae, and photosphere; and bolographs of spot spectra.

d) Spectrographic measurements of the solar rotation, to determine the law of rotation with the lines of various elements, and to detect possible changes in the rotation period. (See also II, *b*), 2.)

e) Miscellaneous investigations, as opportunity may offer, of the spectrum of the chromosphere; the pressure in the solar atmosphere, etc.

IV. STUDIES OF THE TOTAL SOLAR RADIATION

a) Frequent determinations of the total solar radiation, involving measures with the pyrheliometer at various altitudes of the Sun, and simultaneous bolographic records to give the absorption of the Earth's atmosphere.

b) Frequent determinations of the absorption of the solar atmosphere for light of various wave-lengths, to detect any possible changes in absorption that might account for observed changes in the total radiation.

c) Occasional supplementary observations on Mount San Antonio, ($24\frac{1}{2}$ miles = 39.4 km from Mount Wilson) at an altitude of 10,100 feet (3,050 m).

[1] These photographs may also serve to record such exceptional phenomena as the remarkable disturbance of the reversing layer described in a previous paper (*Astrophysical Journal*, **16**, 220, 1902).

d) A comparative study of different types of pyrheliometers.

V. LABORATORY INVESTIGATIONS

a) A study of the lines affected in sun-spots under various conditions of temperature, pressure, etc.

b) Determinations of the pressure-shifts of certain solar lines.

c) Other similar investigations.

With a few exceptions, these investigations are now in progress at the Solar Observatory. Direct photographs of the Sun are taken daily, but large-scale photographs of details have not yet been started. The daily spectroheliograph routine includes H_1, H_2, $H\delta$, and λ 4045 (*Fe*) photographs of the disk, and H_2 (composite) photographs of the flocculi and prominences, all on a scale of 6.7 inches to the Sun's diameter. (See *Contribution* No. 7.) Special studies with the spectroheliograph are also in progress. An account of the work on spot spectra and on the motion of the calcium vapor may be found in *Contributions* Nos. 5 and 6. Special apparatus for the spectrographic study of the solar rotation has been nearly completed in our instrument shop. The study of the solar radiation has so far been confined to the investigations of the Smithsonian Expedition (June–November 1905), but arrangements have been made to continue this work next year. In the laboratory an investigation has been undertaken of the effect of a magnetic field on lines that are widened in sun-spots.

There are many solar investigations not included in this program which offer important returns to careful observers. In visual observations attention may well be directed to such matters as the brightness of the inner extremities of the penumbral filaments; the relative width of these filaments in large and small spots; the evidence for and against cyclonic motion in spots; the changes in the peculiar patterns frequently assumed by the photospheric granules; the character of the granulation in the faculæ, etc. Large-scale photographs, like those of M. Janssen, may also be used in the study of such questions, but the most minute phenomena can be observed only visually. The chromosphere and prominences offer an excellent field for the visual study of details, in addition to the statistical studies of the Italian spectroscopists and other observers, which should be continued and extended. At times of good definition, the spectrum of the chromo-

sphere will richly repay observation with powerful instruments. The same may be said of spot spectra, where many observers can find profitable employment.

The above investigations are mentioned merely as examples of the innumerable opportunities open in solar research. As I hope to show at some future time, the amateur, even if his instrumental equipment be a very modest one, may do work of the highest value, if he will plan it intelligently. A careful consideration of the requirements of promising researches, and a willingness to co-operate with others, should enable any observer to contribute in an important way to the progress of solar physics.

MOUNT WILSON, CALIFORNIA,
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