(4) The spectra of cluster variables, and probably of Cepheids to a smaller extent, vary continuously during the light period, possibly with discrepancies from maximum to maximum corresponding to the irregularities in the light curves.

As a substitute for the clearly inadequate binary explanation, the writer suggests that recourse be had to interpretations based on the oscillations in the form of isolated stellar bodies. Such periodic disturbances might be set up in various ways, for instance by collisions with smaller masses, and although the ensuing vibration should be perfectly regular in the central mass of the star, it need by no means be so on the radiating surface. The explosive character of cluster variation, the changes in spectral type and other characteristics of the light and spectrum variations might then be the naturally expected consequences of the great temperature and pressure changes and of the probable rupture and scattering of the outer layers of the stellar atmospheres with each pulsation. The velocity variations of Cepheids are always relatively small, and in some conspicuous cases cannot be explained as elliptic motion. Because of their great dimensions, a vibratory change in the radius of only a small fraction of its mean value would give rise to radial motions comparable with those observed. The theoretical possibility of such periodic vibrations in fluid and gaseous bodies has been shown by Kelvin, Ritter, Jeans, Emden, and Moulton. In a gaseous sphere similar in nature to what we might expect to find in the stars, the period of oscillation of a given order depends only on the mean density. Connecting the light changes with the oscillation that is most important and which will persist with undiminished amplitude and period for an extremely long time, the mean density of the star in terms of the Sun is 3.9 divided by the square of the period in hours. For the Cepheids of various spectral types, the densities required by this relation are of the same order as those recently derived for giant eclipsing variables of corresponding spectral class.

SPECTROGRAPHIC OBSERVATIONS OF NEBULAE.

By V. M. Slipher.

During the last two years the spectrographic work at Flagstaff has been devoted largely to nebulae. While the observations were chiefly concerned with the spiral nebulae they also include planetary and extended nebulae and globular star clusters.

Nebular spectra may be broadly divided into two general types (1) bright-line and (2) dark-line. The so-called gaseous nebulae are of the first type; the spiral nebulae of the second type.

Nebulae are faint and hence are generally difficult of spectrographic observation because of the extreme faintness of their dispersed light. In the bright-line spectrum the light is concentrated in a few points; in the dark line (continuous) spectrum it is spread out along its whole length. Hence linear dispersion does not affect directly the brightness of the one but vitally that of the other. Thus while the usual stellar spectrograph may serve in a limited way for the bright-line spectrum it is useless for the dark-line one. This suggests why, until recent years, observations of nebular spectra were devoted chiefly to objects having bright lines. The dark-line spectrum is faint in the extreme. It will not over-emphasize this matter to recall that Keeler in his classical observations of planetary (bright-line) nebulae was able to employ a linear dispersion equal to that given by twenty-four sixty-degree prisms, whereas Huggins was able to obtain only a faint photographic impression of the dark-line spectrum of the greatest of the spirals, the Andromeda nebula.

Unfortunately no choice of telescope—as regards aperture or focal-length or ratio of aperture to focus—will increase the brightness of the spectrum of an extended surface. But the spectrograph greatly influences such a spectrum; and of the spectrograph the camera is the determining factor for brightness. When the one-prism Flagstaff spectrograph used in stellar velocities has its 18.5-inch camera replaced by a 3¼-inch Voigtlander camera it is an efficient instrument for nebular work. This change of cameras increases the speed of the instrument fully 30-fold, while the linear scale of spectrum, in consequence of the powerful prism used, is still one-third that of some instruments now employed elsewhere in stellar velocity work. High angular dispersion is necessary, or at least a good means, for overcoming the photographic difficulty that an absorption line, no matter how dark, can not be recorded by the granular surface of a rapid plate if the line is too fine. In short, there is a limit beyond which it is no longer profitable to narrow the slit. This limit with the Flagstaff spectrograph is rather wide and I have profited by it.

The spectrograph has been attached to the 24-inch refractor and enclosed in a constant temperature case. Seed "30" plates were employed. The comparison spectrum was iron and vanadium.

When entering upon this work it seemed that the chief concern would be with the nebular spectra themselves, but the early discovery that the great Andromeda spiral had the quite exceptional velocity of −300 km showed the means then available, capable of investigating not only the spectra of the spirals but their velocities as well. I have given more attention to velocity since the study of the spectra had been undertaken with marked success by Fath at Lick and Mount Wilson, and by Wolf at Heidelberg.

Spectrograms were obtained of about 40 nebulae and star clusters. The spectrum shown by the spirals thus far observed is predominantly type II (G—K). The best observable nebula, that in Andromeda,* shows a pure stellar type of spectrum, with none of the composite features to be expected in the spectrum of the integrated light of stars of various types and such as are shown by the spectra of the globular star clusters which present a blend of the more salient features of type I and type II spectra.

In the table is a list of the spiral nebulae observed. As far as possible their velocities are given, although in many cases they are only rough provisional values.

N.G.C.	221	Velocity — 300 km	These nebulae are on the south side of the Milky Way.
	224 †	— 300	
	598	—	
	1023	+ 200 roughly	
	1068	+ 1100	
	7331	+ 300 roughly	
	3031	+ small	These are on the north side of the Milky Way
	3115	+ 400 roughly	
	3627	+ 500	
	4565	+ 1000	
	4594	+ 1100	
	4736	+ 200 roughly	
	4826	+ small	
	5194	± small	
	5866	+ 600	

As far as the data go, the average velocity is 400 km. It is positive by about 325 km. It is 400 km on the north side and less than 200 km on the south side of the Milky Way. Before the observation of N.G.C. 1023, 1068, and 7331, which were among the last to be observed, the signs were all negative on one side and all positive on the other, and it then seemed as if the spirals might be drifting across the Milky Way.

N.G.C. 3115, 4565, 4594, and 5866 are spindle nebulae—doubtless spirals seen edge-on. Their average velocity is about 800 km, which is much greater than for the remaining objects and suggests that the spirals move edge forward.

As well as may be inferred, the average velocity of the spirals is about 25 times the average stellar velocity. This great velocity would place these nebulae a long way along the evolutional chain if we undertook to apply the Campbell-Kapteyn discovery of the increase in stellar velocity with "advance" in stellar spectral type.

* The bright lines Wolf thought to be present in this and other similar nebulae he has now come to believe were only contrast effects. He also writes that he gets from a recent plate a velocity of —350 km for this nebula.

† Wright at Lick has kindly communicated to me by letter his observation of this object which results in a velocity of —304 km.

N.G.C. 4594, in addition to showing a velocity of 1100 km shows inclined lines. The inclination is about four degrees at wavelength 4300, or four times that shown by a similar spectrogram of Jupiter. Hence the linear velocity of rotation at a distance of 20 seconds from the nucleus of the nebula is eight times Jupiter's limb velocity, or roughly 100 km. The slit was on the long axis of the nebula which makes the axis of rotation perpendicular to the nebula's plane of greatest extension.

ON THE USE OF A THERMO-ELECTRIC PHOTOMETER FOR THE DETERMINATION OF PLATE MAGNITUDES.

By H. T. Stetson.

The possibility of the thermopile as a substitute for the eye in measuring the blackening of a star image on the photographic plate suggested a series of experiments resulting in a form of apparatus to be briefly described.

The instrument consists essentially of a small pin-hole diaphragm strongly illuminated by a constant voltage lamp. An image of the pin-hole is then formed by suitable lenses on the disk of a surface thermopile specially designed by Coblentz. The thermopile is carefully protected from outside disturbance and connected through a resistance box to a D'Arsonval galvanometer of sensitiveness 0.76 microvolts. The plate which is to be measured is placed on a stage directly over the diaphragm and the galvanometer reading noted when the ray of light striking the thermo-element passes through a free space in the background of the plate in the immediate vicinity of a star image. The star image is then moved directly over the pin-hole, the latter always being of a larger diameter than the image, and the fall in the galvanometer reading due to the absorption of the star image carefully recorded.

It has been found from experiment on plates made with the Dearborn Observatory refractor, using Cramer isochromatic plates and color-filter, that a straight line relation holds over a large range between the magnitude of the star and the fourth root of the fall in galvanometer deflection in the form:

$$m = \alpha - \beta \Delta^{1/4}$$

where m denotes magnitude, Δ the difference between the galvanometer reading for the clear plate and the deflection resulting with the interposition of the star image, and α and β are constants of the plate which may at once be determined when the plate includes two stars of known magnitude.