hand, there seems to be no such correlation in the case of Ca^+; it is actually weaker in the two reddest stars. We may therefore conclude that, in this particular region at least, the two features behave markedly differently; the material which absorbs λ 4430 is more directly connected with that which causes reddening than are the atoms of interstellar calcium.

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POSSIBLE APPLICATIONS OF SUPERNOVAE TO THE STUDY OF THE NEBULAR RED SHIFTS

Among the striking facts concerning supernovae brought to light by recent research are the following: (1) Absolute magnitudes of supernovae at maximum are very similar to the average absolute magnitude of extragalactic nebulae, namely, about -14.[1] (2) The light-curves of three supernovae have now been well determined and show a remarkable agreement in shape.[2] (3) The spectra of all supernovae thus far obtained point to the conclusion that, at similar phases, they are identical except for quite minor differences.[3] (4) The spectra of supernovae seem to terminate rather abruptly in the vicinity of λ 3900, and essentially nothing has been observed in the violet, even below λ 3300.[3] On the assumption that future observations will not seriously modify these statements, it appears that supernovae may be useful in advancing knowledge of the nebular red shift in the following ways.

a) *The nature of the red shift.*—At the present time it is not possible to decide observationally whether the red shift is a true Doppler effect, representing relative motion, or whether it is a hitherto unrecognized phenomenon of a different kind, such as, for instance, the

[1] W. Baade, *Mt. W. Contr.*, No. 600; *Ap. J.*, **88**, 285, 1938.

[2] Light-curves of the supernovae in IC 4182 and NGC 1003 have been published by Baade and Zwicky, *Mt. W. Contr.*, No. 601; *Ap. J.*, **88**, 411, 1938. The third curve referred to is for the supernova in NGC 4636, and I am indebted to Dr. Baade for information concerning it. According to Baade, none of the individual curves deviates from the mean curve by amounts in excess of 0.2 mag. for the first 150 days after maximum.

[3] R. Minkowski, *Mt. W. Contr.*, No. 602; *Ap. J.*, **89**, 156, 1939.

gradual dissipation of photonic energy. The answer to this question is, of course, important in cosmological theory. If, now, the red shift is a Doppler effect, then two events separated by a time interval Δt_0 for an observer in a nebula whose velocity of recession is V will appear to a terrestrial observer to be separated in time by an interval $\Delta t = \Delta t_0 (1 + V/c)$. Hence, the light-curve of a supernova occurring in such a nebula should appear to be expanded along the time axis in the ratio $(1 + V/c):1$ with respect to the "standard" light-curve given by relatively near-by objects.

The possibility of making observations on sufficiently distant objects to carry out this test must be considered. For the sake of argument let us take $V = 10^5$ km/sec. This velocity would slow down the apparent rate of development of a supernova to three-fourths of its normal rate and might be considered as a fairly gross effect. The velocity-magnitude relationship for clusters of nebulae has been given by Hubble,[4] and from it we deduce that a typical nebula whose $V = 10^5$ km/sec would be of about the twenty-first photographic magnitude. The average supernova in these distant systems would not, however, be even approximately as bright photographically as the nebulae themselves because the red shift would move the great gap in the violet into the ordinary photographic region. Hence, unless the supernova spectrum contains extremely strong radiations in the λλ 2300–2900 region, it is probable that supernovae could not even be detected in twenty-first magnitude nebulae on blue-sensitive emulsions. The work would therefore have to be carried on in the red, but with modern photographic material this fact should offer no serious difficulty. The number of faint nebulae available for observation is enormous; and since exceptional supernovae, such as the one in IC 4182, are known to be at least two magnitudes brighter at maximum than the average nebula, one may tentatively conclude that the foregoing test, while undoubtedly difficult, is within the bounds of possibility.

b) *Extension of the velocity-distance relation beyond the range spectroscopically observable.*—The peculiar character of the supernova spectrum suggests that the relative brightnesses of these objects in

[4] *Mt. W. Contr.*, No. 549; *Ap. J.*, **84**, 270, 1936.

properly selected regions in the red and in the blue should be a rather sensitive measure of the red shift to which the spectrum is subjected. Thus, color determinations of supernovae at known phases might be used to extend the distance-velocity relation, at least approximately, to distances so great that direct spectrographic determinations are impossible.

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