be noted that energetic collisions can result in ions with multiply excited electrons, and some of the unclassified lines may arise from this mechanism. Further study is necessary to explore the intensity behavior of the emission lines, since our preliminary experiments show that the relative intensities of the lines are energy-dependent.

It must be recognized that Edlén in particular has advanced the state of the spectroscopy of ionized species up to the observation of Cu XIX (1936), and to study higher stages of ionization one must use multiple stripping stages in an accelerator. We do feel that our experiment has opened a new technique that has quantitative as well as qualitative aspects. The technique of using accelerated atomic species, for instance, offers a direct method to determine the lifetimes of the atomic-energy states. One can determine lifetimes by measuring the intensity as a function of distance downstream from the exciting foil. Such measurements enable one to distinguish the components of a blend even when they cannot be resolved spectroscopically. Since the emitting states are not likely to have the same lifetimes, a plot of log I versus distance will show a non-linear relationship from which the relative intensities of the contributors can be found.

The most intense radiations from the atomic beams will lie in the vacuum ultraviolet. We are currently extending our observations to other elements and plan to extend our observations into the $\lambda < 3500$ Å region, although the problems presented by low-source intensity and Doppler broadening will challenge experimental techniques. Among other things, such experiments should be helpful in deciphering the solar spectra explored by Detweiler, Purcell, and Tousey (1960) and the pending observations under the NASA Orbiting Astronomical Observatories program on celestial sources.

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INTENSITY VARIATIONS OF 3C 48, 3C 196, AND 3C 273 IN OPTICAL WAVELENGTHS

The optical objects which have so far been identified with radio sources of the 3C 48 type are unlike anything heretofore known. Maarteen Schmidt's remarkable discovery (1963) that members of the class possess large redshifts showed that objects of this type are not only located at large distances from the Galaxy but also that they are the most luminous objects known in the universe. For example, 3C 48 radiates the enormous power of 1.3×10^{45} erg/sec over the optical region extending from $\lambda_0 = 2340$ Å to $\lambda_0 = 4390$ Å as computed from (1) the observed flux of 1.0×10^{-29} W/m^2 cs at $\lambda = 5000$ Å (see Matthews and Sandage 1963, Table 6); (2) a redshift of $\Delta\lambda/\lambda_0 = 0.3675$ (Greenstein and Matthews 1963); (3) the band pass of the optical spectral region from $\lambda = 3200$ Å to $\lambda = 6000$ Å in the laboratory system; and (4) an assumed distance of 1.0×10^9 pc obtained from the redshift and a Hubble constant of 100 km/sec 10^6 pc.

In view of these high-power levels, it is exceedingly surprising that variations in the optical flux have been observed in 3C 48, 3C 196, and 3C 273. Three-color photoelectric observations of 3C 48 on the *UBV* system were made in October, 1960, as part of the discovery procedure (Matthews and Sandage 1963). Photoelectric observations have been continued to the present with the results shown in Figure 1 and Table 1. These

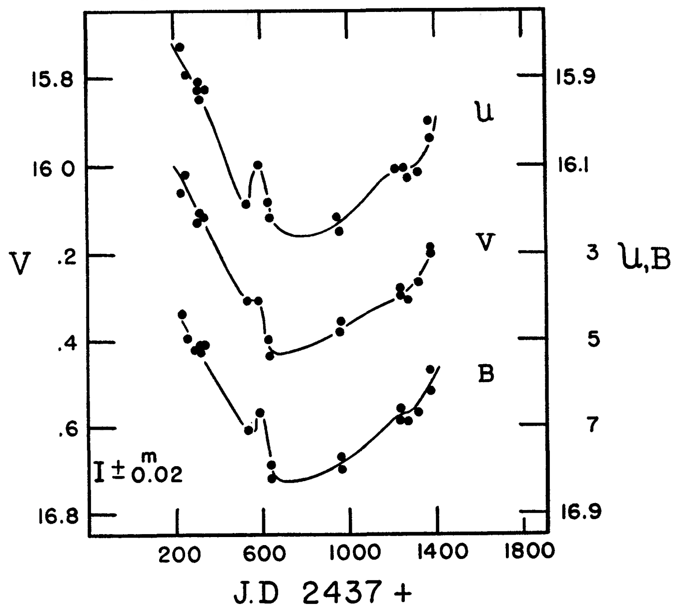

FIG. 1.—The light-curve in three wavelength bands for 3C 48. The left ordinate is the scale for V magnitudes. The right ordinate is the scale for U and B magnitudes. The data are from Table 1.

data show that the optical flux has changed by a factor of 1.4 at all three wavelengths over a period of approximately 600 days. This corresponds to a *change* of power output by about 4×10^{44} erg/sec—a value so large that the reality of the variation might well be questioned. The probable error of a single measurement in each color is about $\pm 0^{\mathrm{m}}.02$, a value which is twenty times smaller than the observed variation. Because of this fact and because (1) two comparison stars which were observed before or after each observation of 3C 48 were constant to within $\pm 0^{\mathrm{m}}.03$ and (2) the light-curves in all three colors are in phase, there can be no doubt that the long time-scale variation shown in Figure 1 is real. On the other hand, the short-term fluctuations near JD 2437600 and 2438300 with a characteristic period of 50 days are not well established, even though the amplitude of the variations is somewhat larger than the probable error. Special observations were made on three nights (October 22/23, 1962, October 23/24, 1962, and October 14/15, 1963) to monitor very short-term fluctuations of the order of minutes or hours. No variation greater than the probable error of $\pm 0^{\mathrm{m}}.02$ was observed over a time span of three hours on each of the three nights. Therefore, short-term fluctuations larger than 2 per cent appear to be absent.

TABLE 1

PHOTOELECTRIC DATA FOR 3C 48

Date	JD 2437+	V	B	U	$B-V$	$U-B$	Remarks
Oct. 24, 1960	231 8	16 06	16 44	15 83	0 38	−0 61	
Nov. 20, 1960..	258 8	16 02	16 50	15 89	48	− 61	
Jan. 13, 1961	312 8	16 11	16 53	15 92	42	− 61	.
Jan. 14, 1961.	313 8	16 13	16 52	15 91	39	− 61	
Jan. 15, 1961..	314 8	. ..	16 51	15 91	.	− 60	
Jan. 17, 1961..	316 8	16 13	16 53	15 94	.40	− 59	. .
Aug. 18, 1961..	529 8	16 31	16 71	16 19	.40	− 52	.. . .
Oct. 12, 1961.	584 8	16 31	16 67	16 10	36	− 57	Mean of 2
Dec. 5, 1961..	638 8	16 44	16 79	16 22	35	− 57	Data by Baum
Dec. 6, 1961..	639 8	16 40	16 82	16 18	42	− 64	Data by Baum
Oct. 23, 1962..	960 8	16 38	16 80	16.25	42	− 55	Mean of 5
Oct. 24, 1962.	961 8	16 36	16 77	16 22	41	− 55	Mean of 5
July 23, 1963.	1233 8	16 30	16 69	16 11	39	− 58	
July 24, 1963...	1234 8	16 29	16 66	16 11	37	− .55	. . .
Aug. 26, 1963	1267 8	16 31	16 69	16 13	38	− .56	Data by Eggen
Oct. 15, 1963.	1317 8	16 27	16 67	16 12	40	− 55	Mean of 4
Dec. 11, 1963	1374 8	16 20	16.57	16 00	37	− 58	Mean of 2
Dec. 12, 1963	1375 8	16 20	16 62	16 04	0 42	−0 58	.. . .

TABLE 2

PHOTOELECTRIC DATA FOR 3C 273 AND 3C 196

Date	JD 2438+	V	B	U	$B-V$	$U-B$	Remarks
				3C 273			
Feb. 17, 1963	077 8	12.66	12 80	11 91	0 14	−0 89	Mean of 5
Feb. 21, 1963 .	081 8	12 69	12 82	11 93	13	− 89	Data by Eggen
Feb. 24, 1963...	084 8	12 68	12 79	11 90	11	− 89	Data by Eggen
Feb. 27, 1963.	087.8	12.74	12 87	11 96	.13	− 91	Data by Eggen
Mar. 14, 1963	102 8	12.67	12.82	11 93	.15	− .89	Data by Kowal
Mar. 19, 1963..	107.8	12 71	12 87	11 96	16	− 91	Data by Kowal
Mar. 20, 1963..	108 8	12 66	12 83	11 89	17	− 94	Data by Kowal
Mar. 21, 1963 .	109 8	12 74	12 89	11 99	15	− 90	Data by Kowal
Mar. 26, 1963..	114 8	12 73	12.75	11 97	02	− 78	Mean of 3
May 15, 1963..	164.8	12 69	12 87	12 04	.18	− .83	Mean of 2
May 16, 1963..	165 8	12 72	12.88	12.03	.16	− 85	. .
May 17, 1963..	166 8	12 72	12.88	12 04	.16	− .84	. . . . .
May 24, 1963..	173 8	12.76	12.89	12 01	.13	− 88	. .
May 25, 1963	174 8	12.79	12 96	12 07	.17	− 89	.... .
Dec. 12, 1963	375 8	12 85	13.05	12 18	0 20	−0 87	Mean of 3
	JD 2437+			3C 196			
Apr. 1, 1962.	755 8	17 79	18 35	17 91	0 56	−0 44	
May 16, 1963	1165 8	17 69	18 31	17 99	62	− 32	.
Dec. 12, 1963	1375 8	17 45	18 05	17 56	0 60	−0 49	. .

The photoelectric data are less complete for 3C 273. Nevertheless, the results given in Table 2 show beyond doubt that the flux also varies for this object. This result is consistent with the more extensive photographic data of Smith and Hoffleit (1963) and of Sharov and Efremov (1963), which suggest large optical variations. That the variation shown in Table 2 is significant can be proved by noting that the observed magnitude of a nearby comparison star in the field of the radio object is constant to within about $\pm 0^{m}.02$ over the entire interval of 10 months, whereas the magnitude of 3C 273 has decreased by about $0^{m}.20$.

The data for 3C 196 consist of observations on only three nights over an interval of 20.5 months but these show beyond doubt that a variation has also taken place in this object. The data are given in the second part of Table 2 where it is seen that a change of $0^{m}.24$ in V occurred between May 15/16, 1963, and December 11/12, 1963, a value which is considerably larger than the probable error.

Because the first three objects studied have shown variability, it now becomes important to monitor all objects of the class (nine are known at this writing). The cause of the light variations is unknown at present, but whatever the mechanism, it apparently does not change the wavelength dependence of the optical radiation by a large factor because Tables 1 and 2 show that both $B - V$ and $U - B$ have remained nearly constant. It is of course important to extend the wavelength coverage, especially into the radio region, to decide between various mechanisms. Among many possible causes of the optical variations might be (1) a change in the high-frequency cut-off of relativistic electrons by new injections and subsequent energy decay, if indeed the optical flux is caused by synchrotron radiation (but here the color index of the optical light should change); (2) a variation of the electron density of a high-temperature gas ($T_e = 50000^{\circ}$ K) radiating by free-free and free-bound emission; and (3) storage and release of energy by an Eddington valve process similar to that in pulsating variables.

Systematic observation of all members of this class of objects is now under way, and it may eventually be possible to establish if the variations occur in all objects of this type and if the variations are periodic or of a random nature.

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THE OPTICAL IDENTIFICATION OF THREE NEW RADIO OBJECTS OF THE 3C 48 CLASS

The identification of the radio sources 3C 48, 3C 196, and 3C 286 with an entirely new class of optical object (Matthews and Sandage 1963), and the subsequent discovery that objects of the class possess large redshifts (Schmidt 1963), have opened up powerful new possibilities for study of the cosmological problem. Because so few of these objects are known, many of their physical and spatial properties are, for the moment, obscure. For this reason a systematic search for additional objects of this type has been started at the Mount Wilson and Palomar Observatories and at the Mullard Radio Astronomy Observatory.