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1418+54: A NEW, VIOLENTLY VARIABLE BL LACERTAE OBJECT

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ABSTRACT

The new BL Lacertae object, 1418+54, has been found to exhibit large-amplitude optical variations on a time scale of days to years. The historical light curve of this object, as determined from a search of the archival plate collection of the Harvard College Observatory, indicates that it has a total range $\gtrsim 4.8$ mag. The long-term optical variability does not exhibit any obvious periodicity and implies source dimensions $\sim 1.6 \times 10^{-3}$ pc or less based on light travel time arguments. The variations that are observed are consistent with a multievent source model, similar to that proposed by Dent to account for the radio variability of extragalactic objects. However, the observed rate of change in brightness of 1418+54 is not consistent with the hypothesis that the individual events are due to Type II supernovae explosions.

Subject headings: BL Lacertae objects — radio sources: variable

I. INTRODUCTION

BL Lacertae objects optically exhibit large-amplitude variations which may occur on a time scale of from days to months (Kinman 1976). They also exhibit a significant and variable optical polarization (Tapia *et al.* 1977). The spectra of this class of objects are characterized by the absence of discrete emission features (Stein, O'Dell, and Strittmatter 1976). However, faint absorption features have been found to be present in the spectra of several of these objects (Carswell *et al.* 1974; Oke and Gunn 1974; Ulrich *et al.* 1975; Disney, Peterson, and Rodgers 1974; Oke 1978; Miller and Hawley 1977).

BL Lacertae objects are optically generally identified with radio sources which display rapid variations in the radio flux and linear polarization. Recently, Kühr (1977) has identified optical counterparts for a number of extragalactic radio sources included in the NRAO–Bonn 5 GHz survey. One of these sources, 1418+54 (=OQ + 530), was identified with a 15.0 mag stellar object. Spectra of this object obtained by M. Schmidt (private communication) at the 5 m Hale telescope indicated that no discrete emission features were present, thus suggesting that this object might belong to the BL Lacertae class of objects.

A search of archival plates at the Harvard College Observatory was therefore undertaken in an effort to determine whether this object was variable. The purpose of this *Letter* is to report on the long-term optical variability of 1418+54 as derived from archival plates.

II. DATA REDUCTION AND ANALYSIS

The optical data for 1418+54 were obtained from an examination of plates taken from as early as 1890 to 1977 and kept on file in the archive plate collection of the Harvard College Observatory. In addition, several recent plates have been obtained by using the 30 inch (76 cm) telescope of the Bradley Observatory located on the campus of Agnes Scott College.

Magnitudes for 1418+54 were determined either by iris photometry of the object and nearby comparison stars or by visual interpolation between comparison stars located near the object on each plate. A *B* magnitude comparison sequence in the field of 1418+54 was obtained through a photographic transfer of the photoelectric comparison sequence for B2 1101+38 (Véron and Véron 1975; McGimsey, Miller, and Williamon 1976) to this field.

The accuracy of the iris photometry was determined by constructing a calibration curve for each plate measured, using the iris readings and the *B* magnitudes of the stars of the comparison sequence. The rms scatter of the comparison sequence about the calibration curve may then be used as an indication of the reliability of the magnitude determined from a particular plate. Typically the scatter of the comparison sequence about the calibration curve was 0.1–0.2 mag.

The accuracy of the visually interpolated magnitudes has been determined previously by the author by comparing the magnitudes obtained for an object, using visual estimates with magnitudes determined by iris photometry (Miller 1975, 1977). The visual estimates were found to agree with the magnitudes determined from iris photometry to within ± 0.21 mag. This was found to be in good agreement with earlier analyses which indicated that the visually interpolated magnitudes agreed with iris-photometered values to within ± 0.17 mag (Angione 1973) and ± 0.20 mag (Pollock 1975), respectively.

III. RESULTS

The optical counterpart of 1418+54 was detected on 238 archival plates. The light curves for 1418+54, for the periods 1900 to 1952 and 1967 to 1977, are shown in Figures 1 and 2, respectively. This BL Lacertae object is an active, rapid variable, attaining its maximum detected brightness of 11.3 mag on 1901 April 27. In addition to this outburst, which also happens to be observed on the earliest plate on which this object was detected,

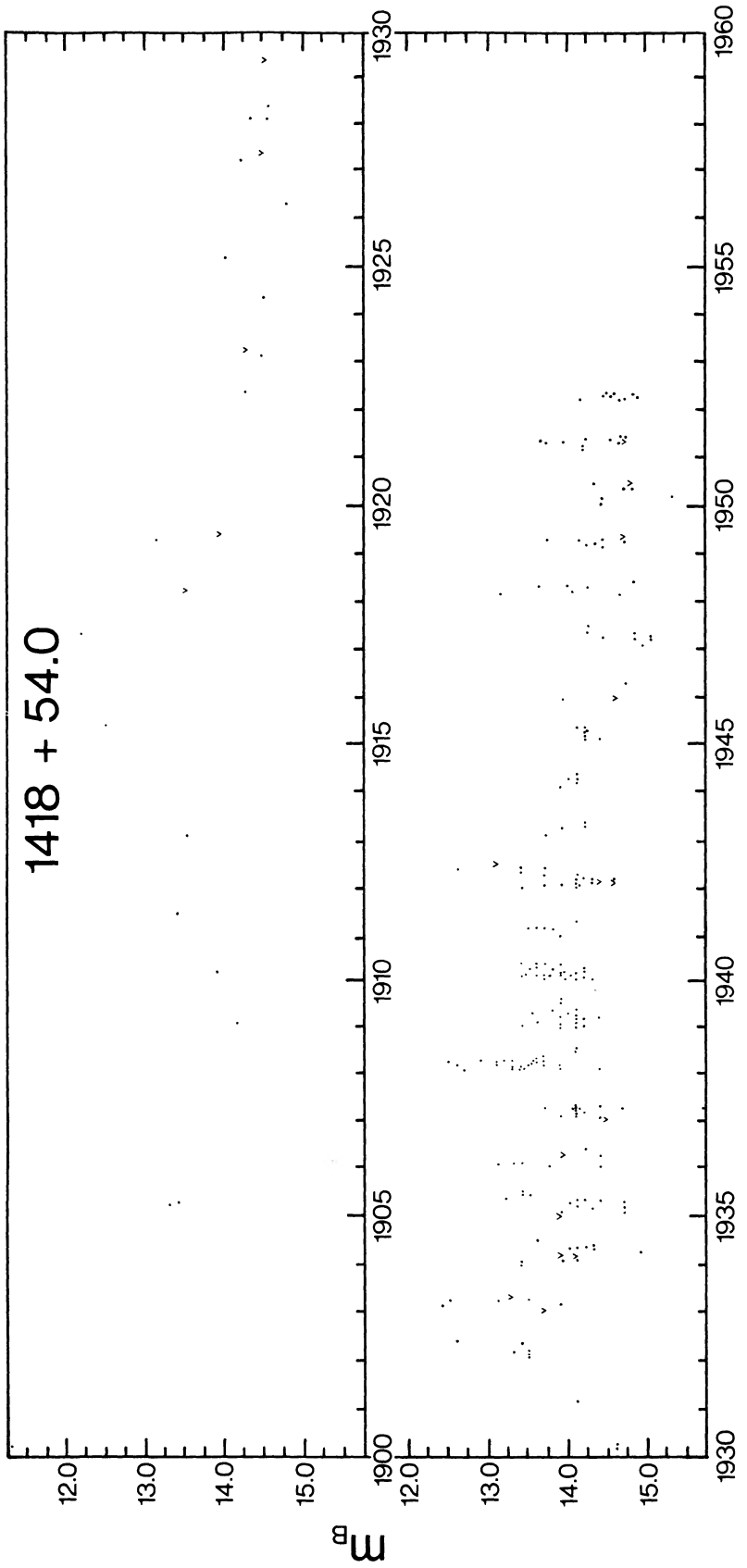

FIG. 1.—The historical light curve of 1418+54 from 1900 to 1952 determined from plates in the archival collection of the Harvard College Observatory

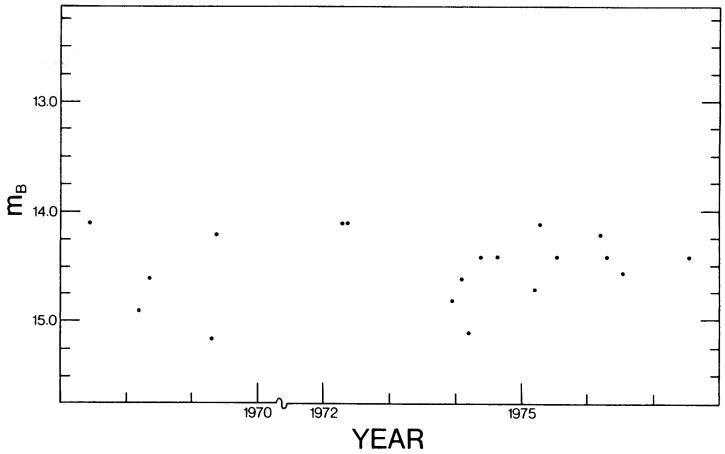

FIG. 2.—The historical light curve for 1418+54 from 1967 to 1977 determined from plates in the archival collection of the Harvard College Observatory.

this object has been brighter than 13.0 mag on several occasions. Outbursts at this brightness level have been detected in 1915, 1917, 1932, 1933, 1938, and 1942. It is obvious from the light curve that outbursts of this magnitude do not occur at regularly spaced intervals but appear rather as erratic, random events.

Throughout the period from 1932 to 1952, 1418+54 was detected on a large number of plates and therefore its optical activity is better documented for this period than for any other. Three of the outbursts pointed out in the preceding discussion occurred during this time; the one detected in 1938 is the best observed and the most interesting.

During the outburst of 1938, the source was observed to undergo violent changes in brightness on the time scale of a few days or less. The source reached a maximum brightness on 1938 March 22 of 12.5 mag. On March 27, the source was still observed to be at 12.7 mag. However, two plates, taken on March 24 and 25, indicate that the source is at 13.7 mag and 13.6 mag, respectively. Thus the source declined 1.2 mag in 2 days' time and then brightened again by 0.9 mag in a 2 day time interval. These two events are the most rapid variations detected and imply dimensions for the emitting region of at most 1.6×10^{-3} pc, on the basis of light travel time arguments. In addition, the source was observed at 15.7 mag on 1937 April 12, which indicates that the source brightened by 3.2 mag in approximately 11 months leading up to this outburst. While this rapid rise is one of the most violent events detected for a BL Lacertae object, it unfortunately was not well observed.

In recent years, 1967–1977, the source has exhibited no violent outbursts; its brightness level has remained typically between 14.0 mag and 15.0 mag (Fig. 2). However, a recent plate taken with the f/15, 30 inch telescope at the Bradley Observatory on 1978 February 12 indicates that the object is presently at 16.1 ± 0.09 mag the faintest that it has been detected in this investigation. Thus the total range observed for this object is 4.8 mag, which places it among those BL Lacertae objects which are the most violently variable.

In order to determine whether any long-term periodic component might be present in the optical variations detected for 1418+54, the average magnitude of the source was plotted for each observing season and is shown in Figure 3. While there are several maxima observed, there is no clear evidence for any periodicity in the long-term light curve. The overall behavior observed is one of large-amplitude, erratic fluctuations in brightness, superposed on a long-term decline from 1900 to 1947. The source appears moderately quiescent from 1947 to 1977, on the basis of somewhat incomplete observations spanning this period.

IV. DISCUSSION

The erratic optical variability observed for 1418+54 is consistent with a multievent source model similar to that suggested by Dent (1972*a*, *b*) to account for the radio variability. Pomphrey *et al.* (1976) have shown that the optical and radio variability are uncorrelated (except in the case of OJ 287) for a number of sources, and they have pointed out that if the outbursts are confined to limited regions of the spectrum, as suggested by this lack of correlation, the energy associated with each outburst is the same order of magnitude as that associated with a Type II supernova. Miller (1977) has noted that the light curves for some sources do resemble those of Type II supernovae. He has also pointed out that if the rates of decline in brightness for BL Lacertae objects can be shown to be significantly more rapid than 0.25 mag per day, then models which appeal to supernova-type events to account for the variability and explain the large amount of energy released in each outburst could be ruled out. When this test is applied to 1418+54, the 1.2 mag decline in 2 days' time (1938 March 22 to March 24) observed for this source rules out Type II supernova as the mechanism responsible for the optical variability and energy output of this object.

The general nature of the light curve for 1418+54 is similar to that observed for B2 1101+38 (Miller 1975) in that it consists of rapid, erratic variations in bright-

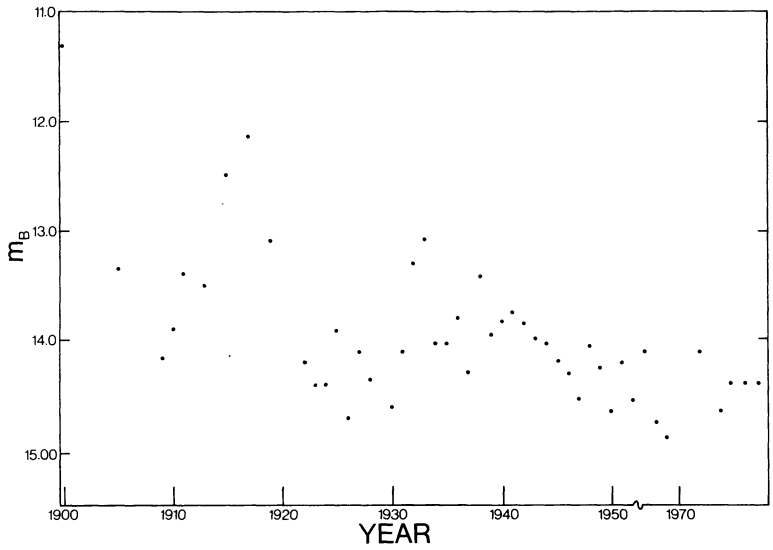

FIG. 3.—The long-term light curve for 1418+54 constructed by using the average B magnitude for this source for each observing season

ness which occur on a time scale ranging from days to months (Fig. 1). In addition, no clear-cut, long-term trends are evident in the light curves for either of these objects (Fig. 3). The total detected range for B2 1101+38 is 4.7 mag, which is nearly identical to that detected for 1418+54 (4.8 mag), and the dimensions of the emitting regions are similar ($\lesssim 2.5 \times 10^{-3}$ pc for B2 1101+38 and $\lesssim 1.6 \times 10^{-3}$ pc for 1418+54). Optically, however, 1418+54 appears completely stellar, while B2 1101+38 is embedded in an E galaxy. Therefore, a detailed study and comparison of the characteristics of these two BL Lacertae objects at optical, infrared, radio, and possibly X-ray wavelengths might provide some insight into the nature of those BL Lacertae objects embedded in galaxies and of those which exhibit no obvious galaxy component.

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Note added in proof.—E. Craine and S. Tapia have independently identified the object 1418+54 (=OQ + 530) as a BL Lacertae object on the basis of the presence of a highly polarized optical flux.

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