4. Microlensing Candidates

The theoretical microlensing magnitude variation has been fitted to the observed light curves after a preselection made among the time series, on the basis of consecutive three-σ deviations with respect to the minimum. The achromatism of the amplifications can be checked only for stars which, when not amplified, are sufficiently above the limiting magnitude of the red plates. The resolution is also better for the IIIaJ plates.

From the reduction of the first half of the field so far performed, some ten events appear to be reliable candidates for microlensing amplifications. Two examples, chosen among these, are shown in Figure 1.

Among the candidates, an object with an unusual light curve has been detected with three consecutive peaks within 7 days. This behaviour is quite surprising for an intrinsically variable object, and the most likely explanation seems to be an amplification by a double lens (Alard et al., 1995). The possibility of observing microlensing by multiple lens, anticipated by Mao and Paczynski (1991), has already been put forward by the OGLE group (Udalski et al., 1994b) on candidate OGLE #7, and later confirmed independently by the MACHO collaboration (Alcock et al., 1995b).

The confirmation of the suspected candidates, with characteristic durations ranging from 3 to more than 60 days, will require scanning and reducing the whole stack of plates, including those taken in the U band, in particular to eliminate the possibility that these events are produced by dwarf novae (Della Valle 1994).

5. Variable Stars

Figure 2 displays a set of short-period variables which are representative of the variety of the new interesting objects detected in the DUO field.

Eclipsing binaries represent the dominant population among the variable stars discovered in the course of our survey. The most numerous are contact binaries with periods smaller than one day, followed by Algol-type objects and Beta-Lyr systems, this ranking being consistent with the results obtained by the OGLE group (Udalski et al., 1994a) on 116 eclipsing binaries discovered in the centre of the Baade's Window. The large number of eclipsing objects which will be produced by the DUO survey is expected to make possible statistical investigations of this population which has been only poorly studied up to the present time.

RR-Lyrae stars represent about 20% of the variable objects so far detected in the DUO field. These can be used to map the interstellar reddening, and are also good distance indicators. They are therefore invaluable in investigations of the structure of the Galactic bulge. The latter issue is of prime importance, in particular, for the study of the Bar. Although the existence of the Bar appears to be well established by now, its orientation and axis ratio are still poorly known.

This component of the galactic structure is receiving special attention from the groups involved in microlensing projects (see, e.g. Kiraga, 1994 and references therein, Stanek, 1995 , Zhao et al., 1995, and references therein). The optical depth to gravitational microlensing in the direction of the Galactic bulge appears to be in excess by a factor of 5–10 with respect to the previously expected values (see, e.g. Evans 1994 and references therein). This could be due to bulge-bulge gravitational amplifications, the Bar playing a major role in this process if oriented towards the Sun as proposed by several authors.

6. The Near Future

The reduction of the second half of the field is in progress. Additional observations will be necessary, especially to improve the time base line, as well as to increase the statistics of microlensing events, and for the study of the long-period variables. This is the reason why we have applied for a second run at the ESO Schmidt: IIIa plates and Kodak 4415 Tech Pan films will be taken on La Silla from May to August 1995.

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The Variation of Atmospheric Extinction at La Silla

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1. Introduction

A total of 248,000 stellar photometric measurements have been obtained from the Swiss station at La Silla from July 1977 to August 1994, during about 4400 nights of photometric quality. These seven-colour photometric measurements in the Geneva System (Golay, 1980; Rufener, 1988) have been obtained by using successively two telescopes (40 cm and 70 cm), two photo-electric photometers and one CCD camera, from two different locations on the site of La Silla.

A very homogeneous set of photometric data, and, in consequence, of data on Earth atmospheric extinction in the optical domain has been collected. A first analysis of the atmospheric extinction variations was published by Rufener (1986, hereafter Paper I) for the period from November 1975 to March 1985. The annual and long-term variations were described as well as the effect of the

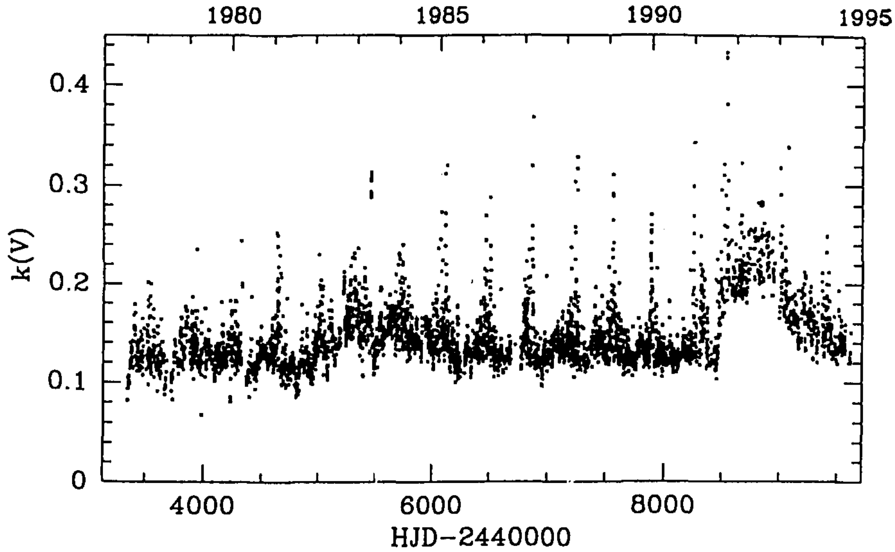

Figure 1: *Variations of the extinction coefficient in the V filter.*

volcanic aerosols injected in the Earth atmosphere by the eruption of the El Chichon volcano.

This problem has been revisited on the basis of the new photometric data (Burki et al., 1995, hereafter Paper II) because of: (i) the time period covered by the observations, which is now 17 years; (ii) the atmospheric extinction which has now been evaluated for all the photometric nights (and not only for the so-called MD nights (see Paper I) representing about only 20% of the photometric nights); (iii) the effect of another volcano eruption, that of the Pinatubo, which can be analysed.

2. The Variations of the Extinction

The general characteristics of the variations of the mean atmospheric extinction during the photometric nights of the past 17 years at La Silla are presented in Figure 1 for the filter *V*. The extinction variations can be decomposed into: long-term variations due to volcano aerosols, a mean annual variation and short-term variations due to meteorological aerosols.

2.1 Long-term extinction variations due to volcanoes

Two volcanoes are well known to have affected the Earth atmosphere's transparency, in particular at La Silla, during the past years:

El Chichon in Mexico (latitude +17°) had two eruptions, in March 23 and April 4, 1982 (HJD 2445051 and 2445064). The stratospheric loads due to El Chichon is estimated to reach about 8 megatons of sulphur dioxide SO_2, a radiatively very efficient absorbant when transformed into sulphuric acid by photochemical effect in the presence of water vapour (Mroz et al., 1983; McCormick & Swissler, 1983).

The Pinatubo in the Philippines (latitude +15°) had also two main eruptions: the first of four pre-paroxysmal vertical eruptions took place on June 12, 1991 (HJD 2448420), and the main eruption on June 15, 1991 (HJD 2448423). The estimation of the amount of SO_2 emitted to the atmosphere is about 20 megatons (Bluth et al., 1992; Pallister et al., 1992).

As shown by Figure 1: (i) these two volcanoes can be considered as the cause for the long-term variations of the extinction at La Silla during the past 17 years; (ii) the increase of the extinction at La Silla was very sudden, roughly 150 days (El Chichon) and 100 days (the Pinatubo) after the eruptions; (iii) the effect from the Pinatubo was much stronger than the one from El Chichon; (iv) the decantation of the volcanic aerosols in the atmosphere is very slow, lasting at least 1000 days, perhaps even 1300 days.

Our data permit to follow the evolution of the extinction law due to the volcano aerosols, during some hundreds of days following the eruptions. Adopting a law of the standard form $k(\lambda) \sim \lambda^{\alpha_p}$, we obtain that: (i) the aerosols from the two volcanoes were very different at their origin (or, more precisely, when they were detected from La Silla), the aerosols from the Pinatubo having produced a flater, or gray, extinction law; (ii) the "volcanic aerosols" produce very different extinction laws than the "meteorological aerosols" (see Section 2.2); (iii) the evolution towards an increase of α_p with time, observed in the cases of the two volcanoes, could mean that the volcano

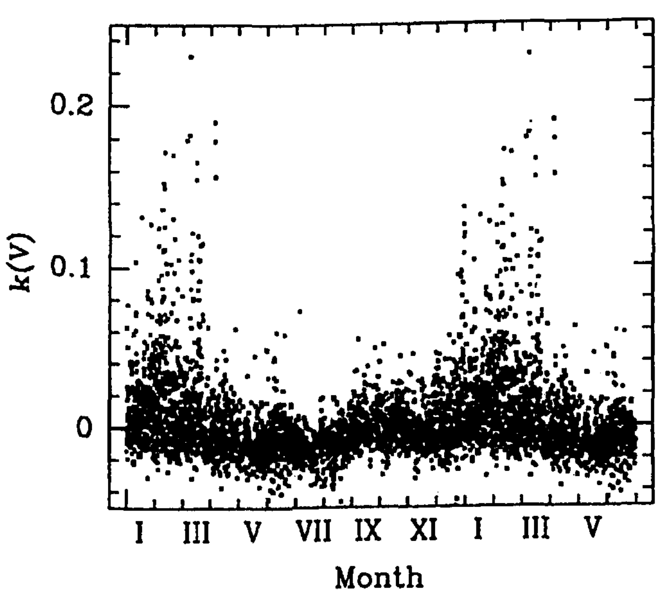

Figure 2: *The annual variation of the extinction coefficient in the V filter.*

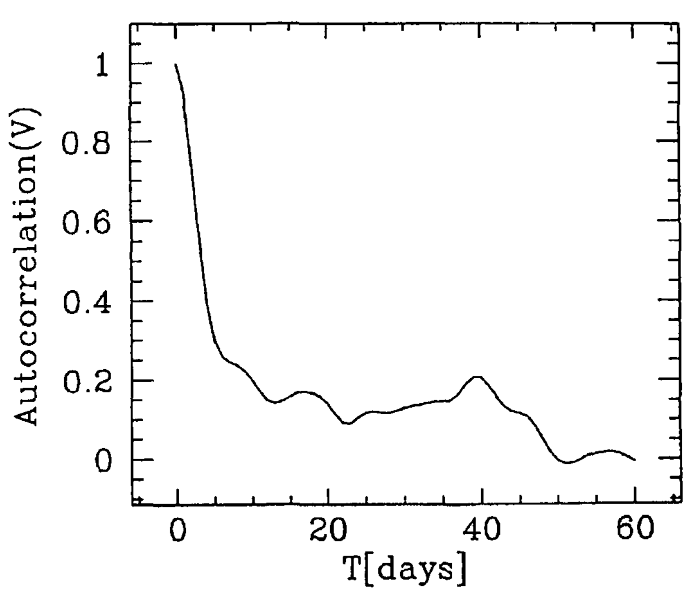

Figure 3: *Analysis of the series of the extinction coefficient determinations in the V filter by autocorrelation.*

aerosols have a size increasing with time, until they fall on the ground.

From the theoretical calculations of the extinction law (van der Hulst, 1952), we derive an increase of the typical aerosol radius from 0.4 to 0.7 μm from HJD 2445170 to 2446030 (El Chichon), and from 0.5 to 0.8 μm from HJD 2448670 to 2449260 (the Pinatubo). Thus, the typical radius was a little larger for the Pinatubo aerosols, and, in the case of both volcanoes, we note *an increase of the typical aerosol radius with time.* These conclusions are in agreement with the results obtained by Hofmann & Rosen (1983, 1987), Knollenberg & Huffman (1983), Oberbeck et al. (1983) in the case of El Chichon and Valero & Pilewskie (1952) in the case of the Pinatubo.

2.2 The annual variation of the extinction

The annual variation of the extinction is mainly due to the variation of the meteorological aerosol content in the atmosphere above the observing site. This variation can be examined by removing the minimum mean extinction values and the extinction due to volcanic aerosols (Section 2.1) to the global data. In addition, for the purpose of this Section, the data from the periods of two years following the eruptions of the two volcanoes have been excluded. The resulting extinction values in *V* have been plotted in Figure 2 versus the date in the year. We see that: (i) the minimum value of the extinction is relatively stable throughout the year; (ii) the maximum values are reached during the first part of the year, i.e. during the southern summer.

The extinction law for these meteorological aerosols has been determined in Paper II (the effect from the volcanoes having been removed): $k_p(\lambda) = b_p \lambda^{-1.39}$. The value $\alpha_p = -1.39$ (the Ångström factor) is remarkably stable and well defined at La Silla. It is known (e.g. Wempe, 1947; Ångström, 1961) that α_p varies within a small range and that, under global, average conditions, at a large variety of locations on the Earth, it has a value close to -1.3 ± 0.2, being seldom above −0.5 or below −1.6. The values of α_p larger than −0.5 are encountered under conditions when the atmosphere is, for instance, polluted by volcanic outbreaks or forest fires. When estimations concern specifically the meteorological haze, the values for α_p are less dispersed, between −1.25 and −1.45, and are independent of the haze density.

The component of the extinction analysed in this Section is related only to the haze present during the nights of very good and stable, *photometric*, atmospheric transparency. This is an indication that the distribution of the radii of the particles forming the haze (mainly constituted of water droplets) is quite stable during these nights and has its mode near the value 0.3 μm.

2.3 Short-term variations of the extinction

Is there any typical period of several days, or weeks, during which the extinction does not vary considerably? Or, in other words, is the extinction in a given night correlated to the extinction of the previous and/or the following night(s)?

Based on our large material, it is possible to give a clear answer to this question, for the La Silla site, since the extinction has been determined during almost all the photometric nights during a period of about 17 years. The best mathematical method to analyse these data is to use an autocorrelation technique. The results, presented on Figure 3, are based on the k(V) values obtained during the years 1985 to 1990 only (HJD 2446066–2448257), in order not to be affected by the effects from the volcanoes. An important autocorrelation appears for a time $T \leq 5$ days, shown up by a decrease of the function from 0 to 5 days: the autocorrelation is very high (0.90) for $T = 1$ day, and decreases until $T \simeq 5$ days. Consequently, *the global tendency is to have series of a few* ($n \leq 5$) nights with similar extinction values.

3. Conclusion

The variation of the atmospheric extinction is essentially due to the meteorological and/or volcanic aerosols. The characteristic time for these variations, *restricted to the nights of photometric quality*, varies from 2–3 hours to several years. The amplitude of these variations is large: during the 4400 nights of our photometric activity, the proportion of the light diffused or absorbed by the Earth atmosphere has varied, in the *V* band, from 9% (minimum extinction) to 33% (beginning of the period affected by the aerosols from the Pinatubo).

In the case of ground-based measurements, the correct estimation of the fluxes "outside the atmosphere" must absolutely be done by using the atmospheric extinction value for the site and at the time the measure has been performed. In the cases of stable photometric nights, the mean value for the night can be used. An estimation based on the extinction values of other nights will give correct results only by chance.

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