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# The Relative Source-Lens Proper Motion in MACHO 98-SMC-1 from Observations by the PLANET Collaboration

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*see acknowledgments*

**Abstract.** Following an alert by the MACHO group, the PLANET collaboration has made detailed follow-up observations of the microlensing event in the SMC, MACHO 98-SMC-1. The lens is a binary and in consequence it is possible to obtain the relative source-lens proper motion as the source crosses a caustic. Two acceptable models have been found to describe the source-lens configuration, both of which suggest that the lens cannot be in the halo of the Galaxy, but is most likely in the SMC itself.

## 1. Introduction

Microlensing survey groups searching for the dark matter component of the Galactic halo have found more than a dozen events so far in the direction of the LMC. The optical depth is about half what would be expected for a full dark halo of MACHOs and far more than can be accounted for by the known populations along the line of sight in the Galactic disk, spheroid and LMC disk. But the event durations together with the well-constrained kinematics of the halo imply masses for the lenses of about $0.4M_{\odot}$. Such objects , if made of hydrogen, would be hard to miss in the halo. Numerous explanations have been offered for the observations, but all present substantial difficulties. Observations of binary lensing events present an opportunity to locate the lens along the line of sight and thus decide in those particular cases whether the lens is in the halo or not.

## 2. Observations

In response to an alert by the MACHO group, the PLANET collaboration carried out intensive observations of MACHO 98-SMC-1 from sites in S Africa, Chile and Australia beginning on 9 May, 1998, one day after the alert was issued. The MACHO group recognised immediately that the event was due to a binary lens, and predicted that a second caustic crossing would occur on 19.2±1.5 June UT. Our data from the period 9 – 17 June allowed us to refine the prediction to

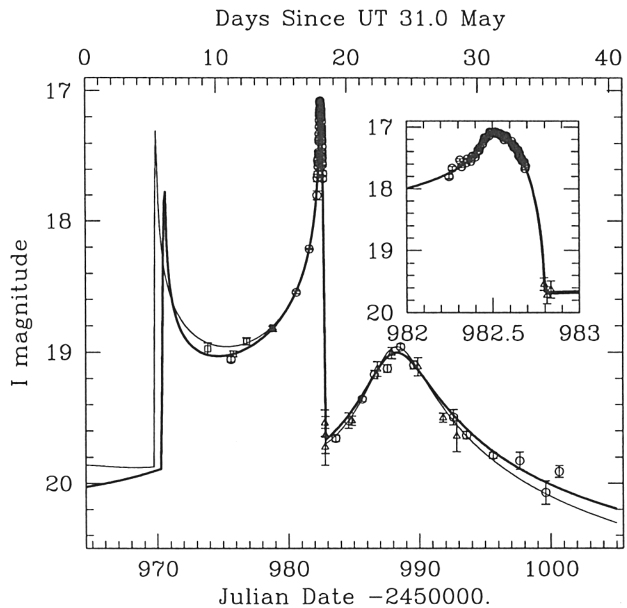


Figure 1. PLANET $I$-band data for MACHO 98-SMC-1 plotted with light curves obtained from 2 similar models, I (bold line) and II (thin line), differing mainly in the angle at which the source star crosses the caustic.

18.0 June UT, in the middle of the observing night at Sutherland. Intensive observations were carried out and the caustic crossing was duly observed at the predicted time with the 1.0-m telescope at Sutherland. Furthermore, a spectrum was obtained around the peak of the crossing with the 1.9m telescope at Sutherland. The light curve to the beginning of July, together with two possible model fits, is shown in Fig. 1. The data are binned on a nightly basis, except near the peak as shown in the insert.

## 3. Discussion

The significance of this event is that the relative source-lens proper motion can be determined from a knowledge of the angular radius of the source star and the time taken to cross the caustic. This in turn allows the location of the lens to be determined.

A nine-parameter model is required to fit the light curve generated by a static binary lens and a uniform surface-brightness finite source. We find two more or less equally acceptable models. While they give almost the same transit time for the source across the caustic (8.52 and 8.46 hours, respectively), the

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angle of crossing is rather different (43.2 and 30.6 degrees, respectively), and hence also the derived proper motion. From our photometry and an estimate of the reddening, the intrinsic colour of the source star can be found. From its position in the colour-magnitude diagram, the source is an A6 dwarf, which is consistent with the appearance of the spectrum also. The derived proper motion is $1.26 \pm 0.10$ km s$^{-1}$ kpc$^{-1}$ for model I and a factor of 1.59 times greater for model II. A comparison of the derived proper motion with the distribution expected from a standard isothermal halo rotating at 220 km s$^{-1}$ with the source in the SMC at 60 kpc, indicates that there is a negligible chance that the lens is in the halo.

Alternatively, we can assume the lens is in the SMC. Taking the SMC to be a one-component system with velocity dispersion 21 km s$^{-1}$ we find that some 9% of events could have a proper motion greater than that found for model I, while <0.1% would have proper motions greater than for model II. But is is known that there is considerable structure in the radial velocity map of the SMC, suggesting there might be multiple components along the line of sight moving with comparatively large relative velocities. It is plausible that there is material in the SMC that could produce the observed relative proper motion. If the lens is indeed in the SMC then the durations implied by the models lead to masses characteristic of a typical low-mass binary.

The details of the discussion and references can be found in Albrow et al. (1999).

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## References

Albrow et al. (The PLANET Group). 1999, ApJ, 512, in press (astro-ph:9807086)

## Discussion

*Lynden-Bell:* Presumably what you mean is the relative proper motion of the lens and the source.

*Menzies:* Yes, you are perfectly correct.

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