POLARIZATION IN MICROLENSING EVENTS

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Gravitational microlensing, initially developed to search for MACHOs (Massive Astrophysical Compact Halo Objects) in the Galactic halo by long observational campains towards several directions in the sky [5] [2] [6], has become nowadays a powerful tool to investigate several astrophysical phenomena (see references in [4]). Microlensing observations have been used: *i)* to map the amount and distribution of luminous matter in the Galaxy, Magellanic Clouds and M31; *2)* to undergo detailed studies of different classes of variable stars which actually do change their brightness intrinsically (due to changes in size and temperature); *3)* to study the surface brightness of several stars via the detection of limb darkening effects (this is a crucial ingredient in microlensing light curve fitting in case of source stars showing large finite source effects); *4)* to discover and fully characterize exoplanetary systems, via the detection of deviations in the microlensing light-curves expected for single-lens events (up to now 15 planetary systems in the Galaxy and possible 1 in the M31 galaxy have been detected).

Here, we show that during a microlensing event a characteristic polarization signal of the source star light may rise, depending on the source star type and the involved polarization process. The polarization signal is maximized in events showing large finite source effects (the source star radius is greater than the lens impact parameter u_0) and high magnification (the trajectory of the source star in the lens plane passes near a caustic).

Polarization of the stellar light is caused by photon scattering: *1)* in the free electron atmospheres of Hot Stars (O, A, B classes) for which the passing light is Thomson scattered by free electrons. The effect has been completely studied by Chandrasekhar [1]. However, these stars are rather rare and indeed, no source stars of this type have been observed in microlensing events; *2)* by the coherent Rayleigh scattering on neutral hydrogen amd molecules in the atmospheres of main sequence stars of late type (G, K, M) [10]; these constitude the larger fraction of the source stars in microlensing events; *3)* by scattering of photons off dust grains contained in the envelopes around evolved, cool giants stars (particularly red giant) which have large stellar winds [8,9,3]. Such evolved stars constitute a significant fraction of the lensed sources towards the Galactic bulge, the LMC and the M31 galaxy making them valuable candidates for observing a polarization signal during a microlensing event.

Polarization is currently observed only for the Sun: the polarization degree increases from the center to the star limb, where in the B band it is about 12 per cent. In the case of distant stars, the stellar disk is not resolved and only the overall polarization is relevant. This is zero when the flux from each stellar disk element is the same. A net polarization of the stellar light may be introduced by some suitable asymmetry in the stellar disk (e.g. hot spots, tidal distorsions, eclipses, fast rotation, magnetic fields) and also in the propagation through the interstellar medium.

In the microlensing context, polarization in the source star light is induced since different parts of the stellar disk are magnified by different amounts, namely the lens system produces a gradient of magnification accross the stellar disk. Moreover, due to the relative motion between source and lens system, the gravitational lens scans the disk of the source star giving rise to a time dependent polarization signal. The effect is relevant in events with high magnification gradient (both single lens and binary) and showing large finite source effects.

Following [1], in Ref. [4] we consider the intensities $I_l(\mu)$ and $I_r(\mu)$ along the directions **l** and **r**, as a funcion of $\mu = \cos\theta$ at a point on the stellar disk. Here θ is the angle between the line of sight **k** to the considered point and the normal **n** to the stellar surface; the direction **l** is contained in the plane formed by **n** and **k** and the direction $\mathbf{r} = \mathbf{kxl}$.

The local polarization degree is $P(\mu) = I_+(\mu)/I_-(\mu)$, where $I_+(\mu) = I_l(\mu) + I_r(\mu)$ is the total intensity and $I_-(\mu) = I_l(\mu) - I_r(\mu)$ is the intensity difference. We evaluate the total polarization P by integration on the source star disk. The weigth function is the local magnification A due to the lens system. For single lens events A is given as a function of the distance between the star disk element and the lens [7], in case of binary lenses A is evaluated by using the Inverse-Ray-Shooting method which is based on the ray tracing from the lens plane to the source plane. Finally, by taking into account the nature of the source star, $I_+(\mu)$ and $I_-(\mu)$ are evaluated following [1], [10] and [9] for hot, late type main sequence and cool giant stars, respectively.

We considered a set of 11 highly magnified, single-lens events towards the Galactic bulge, with identified source star type (for details see [4]). These are *transit events* (the source star trajectory in the lens plane crosses the lens) and relatively large values of P are produced at the instants at which the source star disk *enters* or *exits* the lens. The time interval $\Delta T = T_E\sqrt{\rho_*^2 - u_0^2}$ (here T_E is the Einstein time) gives the time duration of the polarization peak, varying from 1 h to 1 day, depending on the source star radius ρ_* and the lens impact parameter u_0, the longer durations for events with larger finite source effects. We find that the polarization signal can reach values as high as 0.04 percent in the case of main sequence source stars and up to a few percent in the case of red giants with extended envelopes (see Fig. 1).

We also considered a set of 6 exoplanetary events. In this case the polarization signal is enhanced when the source trajectory intersects a caustic, central or planetary. Caustics (in number of 2 or 3, depending on the distance between the planet and the hosting star) are the positions in the lens plane at which the magnification is infinite (actually, for real events the total magnification is finite due to the averaging process on the source disk). In the case of 2 events (for more details see [4]), the source *passes* over the central caustic located near the position of the hosting star and the shape of the polarization signal (occurring near the maximum magnification time t_0) is similar to that of single lens events. We also considered 4 exoplanetary events for which the source intersects a planetary caustic: in this case the polarization signal manifests at a time $t \neq t_0$ which is a priory not predictable.

As a last remark, we note that due to the high magnification (up to 12 mag in I band) of the source star, the available instrumentation may already detect a polarization signal down to a precision of few percent: the FORS2 camera on the ESO VLT telescope is able to measure a polarization signal for a 12 mag source star with a precision of 0.1 percent in 10 min integration time, and for a 14 mag star in a 1h.

Hence, polarization measurements during microlensing events may offer the unique opportunity to probe stellar atmospheres of distant stars and may in principle provide independent constraints on the parameters of the microlensing systems.

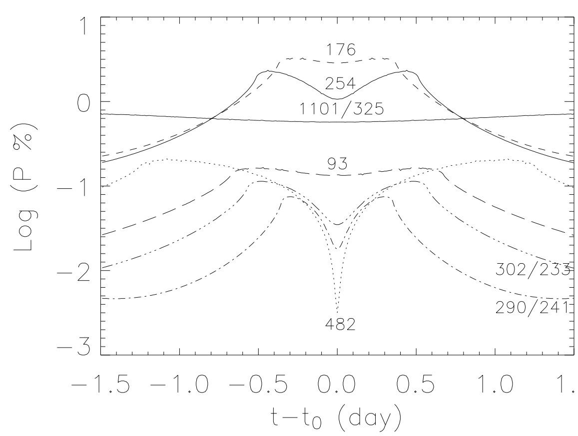

Figure 1. Polarization profiles for 7 single lens events with giant source stars.

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