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FrogEye, the quantum coronagraphic mask.

The photon orbital angular momentum and its applications to astronomy

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Abstract. We propose to realize an optical device based on the properties of photon orbital angular momentum (POAM) to detect the presence of closeby faint companions in double systems using Laguerre-Gaussian (L-G) modes of the light. We test also the possibility of using L-G modes to build coronagraph mask. We realized in the laboratory a prototype using a blazed l=1 hologram to simulate the separation between two stars, as observed with a telescope, in Laguerre-Gaussian modes.

Key words. Instrumentation: miscellaneous, Methods: laboratory, Techniques: miscellaneous

1. Introduction

Photon orbital angular momentum (POAM) [Allen et al. (1992, 2002)] has attracted attention for astronomical applications [Harwit (2003)] and applications at the quantum level for quantum communication [Mair al. (2001); Vaziri et al. (2002); Arlt et al. (1998)]. The generation of beams carrying POAM, described by Laguerre-Gaussian (L-G) modes, proceeds thanks to the insertion in the optical path of a phase modifying device (fork hologram) imprinting a certain vorticity on the phase distribution of the incident beam [Arlt et al. (1999)]. The vorticity is characterized by parameters l and p describing the orbital and azimuthal angular momentum. Here we describe a prototype of a finger mask for binary systems using a $l = 1$ fork-hologram.

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2. The Coronagraph

The coronagraphic mask setup was tested using as source two 632nm He-Ne lasers collimated into our $l = 1$ fork–hologram simulating a binary system having for each star angular diameter of 20marcsec, namely the one produced by a 8.2m VLT-like telescope with adaptive optics. The primary star lies on the center of the optical system, on axis and crossing the fork-hologram singularity, while the light beam representing the secondary star is off-axis. Tilted and displaced beams do not possess a single L-G mode, but show a spectrum of modes that depend on their geometrical properties [Vasnetsov et al. (2005)], which makes possible the detection of a fainter companion.

The light of the main star is spread over the donought-shaped disk, while the fainter companion appears as a modification of the L-G

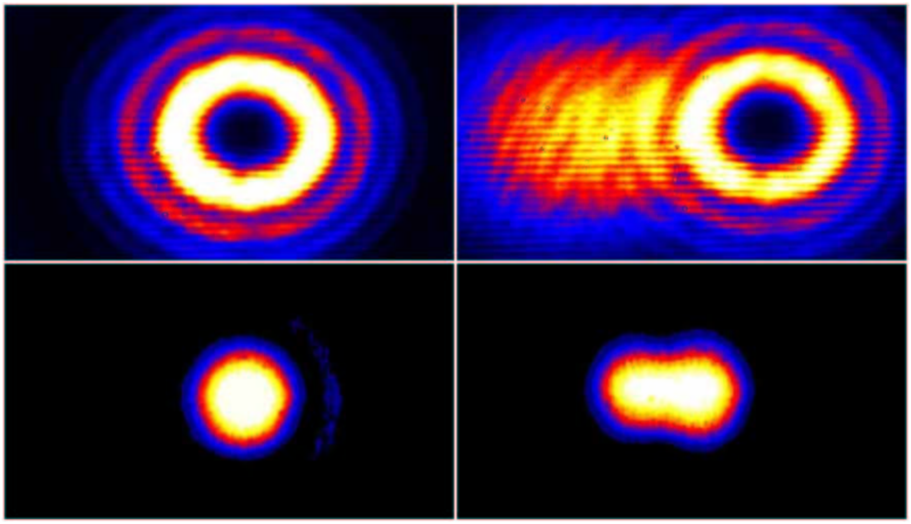

Fig. 1. Upper row, left panel, L-G modes of an unresolved binary composed of two equal intensity stars, right panel, the same pair just resolved according to the Rayleigh criterium. Bottom row: the corresponding gaussian modes.

mode structures of the primary star. By setting the stars at a very small distance for which the star is unresolved, we note that the L-G profile of both the contributions has its characteristic donought-symmetric shape. When the fainter star is resolved following the Rayleigh limit, we see that the first outer ring surrounding the donought becomes brighter and the level of the background in the ring region rises up the more the separated are the sources, thus revealing the presence of a fainter companion. A fork-shaped hologram is equivalent to a set of cylindric lenses as currently used in modern coronagraphs for extrasolar planets and have the same optical properties of modifying the phase of the light. Further tests are currently being performed to improve the contrast of our finger-mask.

3. Conclusions

Photon distribution of light having non null orbital angular momentum presents certain features that could give some advantages to astronomical applications, such as giving better evidence to closeby or fainter sources in a double system.

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