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Speckle Observations of Binary Stars with the MAMA Detector

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ABSTRACT: We have made two sets of speckle observations of binary stars with the Multi-Anode Microchannel Array (MAMA) detector. Our observing system is a true photon counting imaging device which records the arrival time of every detected photon. We present speckle autocorrelation analyses of five binary systems, two observed with the 3.6-m telescope at the European Southern Observatory and three observed with the 40-in reflector at Lick Observatory. These five systems represent a wide variation in separation and magnitude difference that indicate that the MAMA detector is capable of recording high quality speckle data at extremely low count rates and can recover image features very near the diffraction limit of the telescope. In one case, only 10 photons per frame were recorded for the dim companion of the system, and in another case, a separation of $0\farcs157 \pm 0\farcs031$ was derived for a system observed with the 40-in telescope where the diffraction limit is about $0\farcs125$. Future prospects for this system are discussed.

The MAMA detector possesses several characteristics which make it an outstanding choice for the imaging detector in a speckle interferometry system. It has no read noise and usually a very low dark current (~10 Hz). The MAMA also is available in large formats (up to 448×1920 pixels in the current generation of visible light detectors) and has excellent geometric fidelity (Morgan *et al.* 1989, *Appl.Optics*, **28**, 1178). Unlike many speckle systems, the MAMA detector time–tags every event. In the current system, the timing resolution is 400 ns.

Figure 1 shows the basic operation of the detector. An incoming photon strikes a photocathode and may liberate one or more electrons which then travel down through a microchannel in the microchannel plate. At each contact with the microchannel wall, more electrons are liberated until a cascade of 10^5 to 10^6 electrons exits the bottom of the microchannel and strikes an anode array below. The anode array consists of sets of interleaved conducting strips as shown in Figure 1b. By requiring a coincident hit on two or more adjacent anodes, a pixel location can be assigned to an event. A pixel is defined to span from one anode's center line to the next. Figure 1b shows 2 sets of anodes which provide positional information in one dimension. Another pair of anode sets running beneath the first set (but not shown in Figure 1b) is oriented in the perpendicular direction to assign pixel addresses in the second dimension. Each anode is connected to a charge amplifier which outputs a signal level appropriate for the decoding electronics. The decoding algorithm decides what pixel address to assign to an event based on which anodes have been hit, and then passes this to the computer storage interface, which assigns the time tag for the event. Events are then dumped to tape in 1 megabyte sections.

Speckle data have been taken with the MAMA detector on several observ-

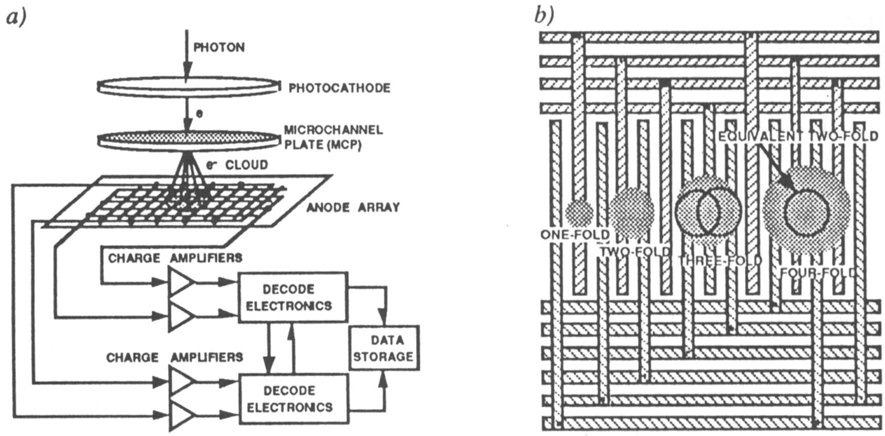

FIGURE 1. a) Block diagram of the MAMA detector operation, b) an illustration of two sets of interleaved anodes with different sized electron clouds.

ing runs over the past 4 years. We present part of the work involving binary stars from two recent observing runs. Figure 2 shows the power spectrum and reconstructed autocorrelation obtained for HD 206058, taken at the European Southern Observatory 3.6-m telescope in 1989. This object has a separation of $\sim 0\overset{''}{.}5$ and was very easily resolved. We were also able to successfully resolve a $0\overset{''}{.}2$ binary at ESO.

In September of 1991, we observed at the Lick Observatory 40-in reflector with a new speckle system which features a virtually noise–free fiber optic link for data transfer from the telescope to the data storage device, a new MAMA decoder which was less susceptible to noise and faster than the old decoder, and a new computer interface. Figure 3 shows the power spectrum and reconstructed autocorrelation obtained for HD 202582, where we measured the separation of the two companions to be $0\overset{''}{.}157 \pm 0\overset{''}{.}031$. Since the diffraction limit of the 40-in telescope is about $0\overset{''}{.}125$ at this wavelength, this new system is capable of obtaining essentially diffraction–limited image information.

TABLE 1. Observational Results on 5 Systems Resolved with the MAMA Detector.

Object	Epoch	Separation (arcsec)	Pos. Angle (degrees)	Δm	Count Rate (kHz)	Events (Mevent)
HD 206058	1989.6	$\sim$0.5	258.1	1.1	12	2.4
HD 201038	1989.6	$\sim$0.2	281.3	1.0	15	2.4
Pair in χ Per	1991.7	2.60$\pm$0.22	319.42$\pm$0.94	2.9	4.0	1.1
HD 199839	1991.7	0.360$\pm$0.041	320.0$\pm$3.4	1.3	8.7	1.6
HD 202582	1991.7	0.157$\pm$0.031	271.0$\pm$7.2	1.6	35	2.2

Table 1 shows these and other results we have obtained to date on binary systems. These systems span a wide range of separation and magnitude difference indicating that the MAMA-based system is a fairly robust one.

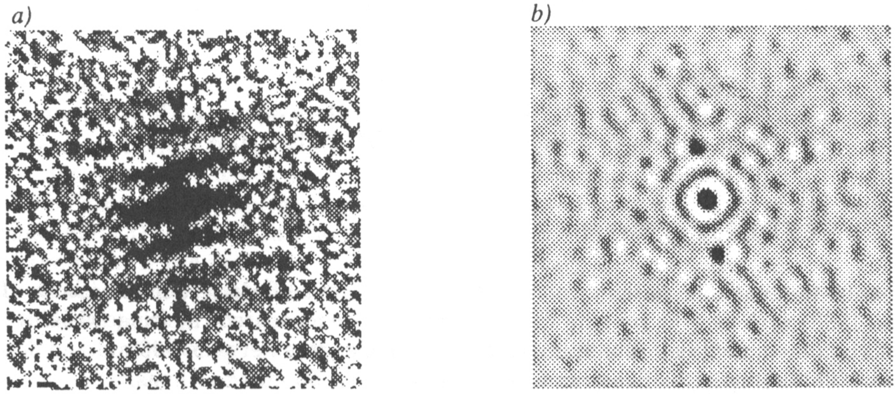

FIGURE 2. **Speckle autocorrelation analysis of HD 206058 (from data taken at the ESO 3.6-m): a) power spectrum, b) reconstructed autocorrelation obtained from (a).**

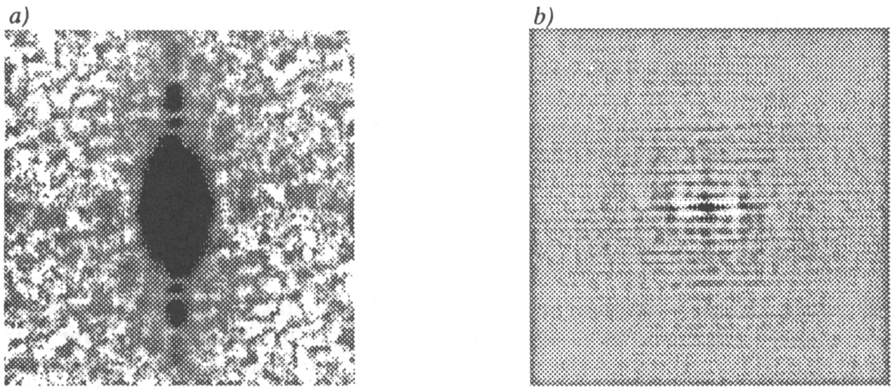

FIGURE 3. **Speckle autocorrelation anaylsis of HD 202582 (from data taken at the Lick 40″): a) power spectrum, b) reconstructed autocorrelation obtained from (a).**

Within the next year, the next generation of visible light MAMAs will be built. These devices will use state–of–the–art charge amplifiers which are much heartier and less sensitive to noise than the current model. One of the new MAMAs will have a trialkali (S-20) photocathode where we can expect quantum efficiency of about 5% at 600 nm. This detector will have a pixel format of 1000×1000. These advances should make for an even stronger system than our current version.

One observing program involving binary stars which we will seek to undertake with the new system is a detailed study of how accurately the MAMA can determine the magnitudes and colors of the companions in close binary systems. We will soon start observations of several binary systems which have a wide enough separation through part of their orbits to be analyzed visually and then take speckle observations throughout the orbit and derive a curve of magnitude error *versus* separation. Also of interest is a curve of magnitude error *versus* magnitude difference of the companions.