The AstraLux large M dwarf survey

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Abstract. AstraLux is the Lucky Imaging camera for the Calar Alto 2.2-m telescope and the 3.5-m NTT at La Silla. It allows nearly diffraction limited imaging in the SDSS $i'$ and $z'$ bands of objects as faint as $i'=15.5\text{ mag}$ with minimum technical effort.

One of the ongoing AstraLux observing programs is a binarity survey among late-type stars with spectral types K7 to M8, covering more than 1000 targets on the northern and southern hemisphere. The survey is designed to refine binarity statistics and especially the dependency of binarity fraction on spectral type. The choice of the SDSS $i'$ and $z'$ filters allows to obtain spectral type and mass estimates for resolved binaries.

With an observing efficiency of typically 6 targets per hour we expect to complete the survey in mid-2009. Selected targets will be followed up astrometrically and photometrically, contributing to the calibration of the mass-luminosity relation at the red end of the main sequence and at visible wavelengths.

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INTRODUCTION

Observations of binary stars can not only constrain stellar formation theories, which have to reproduce the observed binary frequency, but are the only way to reliably determine stellar masses by orbit fitting techniques. While binary statistics are well established for solar-like stars, this is not entirely true for the low-mass and very low-mass end of the main sequence. Here large binarity surveys can still provide substantial improvements of our knowledge of the binary fraction and its dependency on spectral type, giving indirect evidence of a possible discontinuity in the low-mass initial mass function [1].

Apart from that, dynamical mass estimates of low-mass stars are the key ingredient to the calibration of mass-spectral-type and mass-luminosity relations at the red end of the main sequence. While stellar evolution models reproduce near-infrared magnitudes and colours of low-mass stars quite satisfyingly nowadays, this is not the case for visible wavelengths $<1\mu m$.

This is the motivation for the large AstraLux M dwarf survey, designed to find and

1 Based on observations collected at the Centro Astronómico Hispano Alemán (CAHA) at Calar Alto, operated jointly by the Max-Planck Institut für Astronomie and the Instituto de Astrofísica de Andalucía (CSIC).
characterise late-spectral-type binary and multiple systems at visible wavelengths. With more than 1000 M dwarfs targeted by the initial survey programme, this is by far the largest of its kind. The Lucky Imaging cameras AstraLux at the Calar Alto 2.2-m telescope and AstraLux Sur at ESO’s NTT, La Silla, provide the necessary observing efficiency to conduct such a survey in relatively short time.

**THE ASTRALUX CAMERA**

AstraLux$^2$ is a high-speed, high-sensitivity camera with an electron multiplying readout register, allowing single-photon detection at virtually zero readout noise. Its main application is high-angular resolution imaging employing the Lucky Imaging technique$^3$. The original AstraLux camera is a common user instrument at the Calar

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$^2$ [http://www.mpi-a.de/ASTRALUX/](http://www.mpi-a.de/ASTRALUX/)
FIGURE 2. Sample observations of M dwarf multiples with AstraLux at the Calar Alto 2.2-m telescope. The field of view is 2.5×2.5 arcsec. Effective integration times were 30 s in the SDSS z’ filter.

Alto 2.2 m telescope (see Fig.1) since 2007, while its sister instrument AstraLux Sur is an almost identical copy, currently used as visitor instrument at ESO’s NTT telescope at La Silla, Chile.

Both instruments allow nearly diffraction limited imaging in the SDSS i’ and z’ filters, i.e. at wavelengths <1 μm, with typical full width half maxima of the PSF cores below 100 mas and Strehl ratios of up to 20 %. This is achieved by recording several thousand short exposure images (integration time <50 ms) and combining only the best 5–10 % which are least affected by blurring due to atmospheric seeing. In contrast to full-grown adaptive optics systems, this provides high angular resolution imaging capabilities at a fraction of the technical effort and costs, and with considerably smaller instrumental overheads.

Including target acquisition and instrument setup, typically only 10 minutes are needed to perform an observation of one of our survey targets in both SDSS filters. This is faster than the overhead alone as specified for NACO, i.e. a state-of-the-art adaptive optics system. A near real-time pipeline allows the observer to see the final high-quality results only minutes after finishing data acquisition.

The high frame rate of the AstraLux camera (up to several 100 Hz using windowing and/or binning) makes the instrument also a very interesting choice for projects needing high time resolution, e.g. transit observations, stellar occultations by solar system objects, or pulsar timing. Accurate timing of individual exposures with an accuracy better than 1 μs with respect to the UTC timeframe is realised by MicroLux, a custom GPS based timing hardware [4].

SURVEY LAYOUT AND STATUS

Our sample comprises more than 1000 late K and M dwarfs of spectral types K7 to M8.5. Most of the targets were published only recently [5, 6] and have not been observed with high angular resolution instruments before. For most targets of spectral types earlier than M5 spectral typing is based on spectral indices and photometric parallaxes can be assumed to be of relatively high accuracy. Additionally, published X-ray count rates and Hα equivalent widths allow correlations between stellar activity and binary parameters.

All targets are initially observed in the SDSS i’ and z’ filters with effective exposure times of 30 s, allowing detection of substellar companions at distances of up to ≈20 pc. Typical imaging results of AstraLux at the Calar Alto 2.2-m telescope are shown in Fig. 2. Strehl ratios of more than 20 % can be reached for the brighter targets of the
survey under good seeing conditions, and detection limits for close companions are generally better than e.g. compared to speckle interferometric observations, though slightly worse than in the case of high-order adaptive optics systems (see Fig. 3).

Binary parameters are extracted by PSF fitting, and obtained magnitudes and colours are used to estimate spectral types of individual components. All newly found binary or multiple systems will be re-observed at least once to check for common proper motion and hence physical companionship. Systems with short period predictions will further be observed at regular intervals to enable orbit fitting and finally dynamical mass estimates. Additional resolved spectrophotometric observations in the near infrared will complement the AstraLux data and allow a thorough characterisation of these systems.

We have observed already more than 400 targets, and obtained second epoch follow-up for a subset of these sources. We expect to reach the benchmark of 1000 targets in mid-2009. Though full orbital solutions will only be possible in the future, our observations will certainly allow an unprecedented refinement of binary statistics for low-mass stars almost immediately.

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