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First direct imaging detection of the secondary component of α Andromedae with the LBT/SHARK-VIS pathfinder experiment

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We report results of Adaptive Optics (AO)-assisted observations with our new SHARK-VIS Forerunner experiment (hereafter Forerunner-Two) at the Large Binocular Telescope (LBT), which were recently carried out after the first successful tests operated in 2014/15 (Pedichini et al. 2017). SHARK-VIS (Mattioli et al. 2018) is the forthcoming visible high-contrast imager of the LBT, which will be on-sky in 2019 Q4. As a precursor of SHARK-VIS, the Forerunner-Two uses fast-imaging, i.e. it acquires frames at high cadence ($\sim$1 kHz), which enables freezing of both the atmospheric turbulence evolution, whose typical timescales at visible wavelengths are of the order of a few ms (e.g. Stangalini et al. 2018), and the image jitter, 80% of the total amplitude of which is under 100 Hz (Mattioli et al. 2018).

The Forerunner-Two was set up to a plate scale of 5.1 ± 0.1 mas/pixel and equipped with a filter centered at 656 nm and with a bandwidth of 10 nm, in order to have negligible atmospheric differential diffraction. To test the capability of the fast-imaging approach and the performances of the LBT AO system in the visible, we observed the well-known double-line spectroscopic binary system α Andromedae ($d = 29.7$ pc, period $P = 96.69$ d, mag $R = 2.09$; e.g. Branham 2017 and references therein).

Observations were performed at LBT on December 23 2018 (2:15 UT time). A sequence of fast-cadence (1 kHz) short-exposure (1 ms) images were acquired continuously for 1 min, resulting in a data set of 60 000 frames with size 200×200 pixels, corresponding to a field of view of ~ 1 arcsec^2. Due to the short observation time, the field rotation is negligible ($<0.3°$) During the acquisitions the AO system (Esposito et al. 2010) was correcting more than 300 modes in a closed loop at 400 Hz. The seeing was around 1 arcsec, according to the DIMM telemetry.

Among the 60 000 frames acquired, we first selected only the best 219 in terms of their peak intensity, peak roundness, and alignment accuracy. These were then reduced by performing bias correction and post-facto co-registration with sub-pixel accuracy, which allowed us to efficiently remove residual jitter. The selected frames were processed using two types of procedures: a simple average stack, and a speckle-free-imaging (SFI; Li Causi et al. 2018) stack.

The final images provided by these methods are reported in Fig. 1. For the first time we are able to detect through direct imaging the secondary component of the system. In panel *a* the average stack is displayed, where we note that the mean speckle pattern severely hampers the detection of the companion. In panel *b*, we show the SFI result, which provides a much cleaner image where speckles and diffraction rings are removed, thus revealing the blended image of the two components. We performed a double 2D-Gaussian fit on the SFI image to derive the relative positions of the stars. Based on our limited sampling and on the fact that due to AO-residuals the PSFs are not perfect Gaussians, we adopt a conservative error of half a pixel for the derived locations of the sources. Combining this error with the uncertainty on the plate scale, we obtain a separation of 18.3 ± 2.9 mas and a position angle $125° \pm 7°$for the secondary

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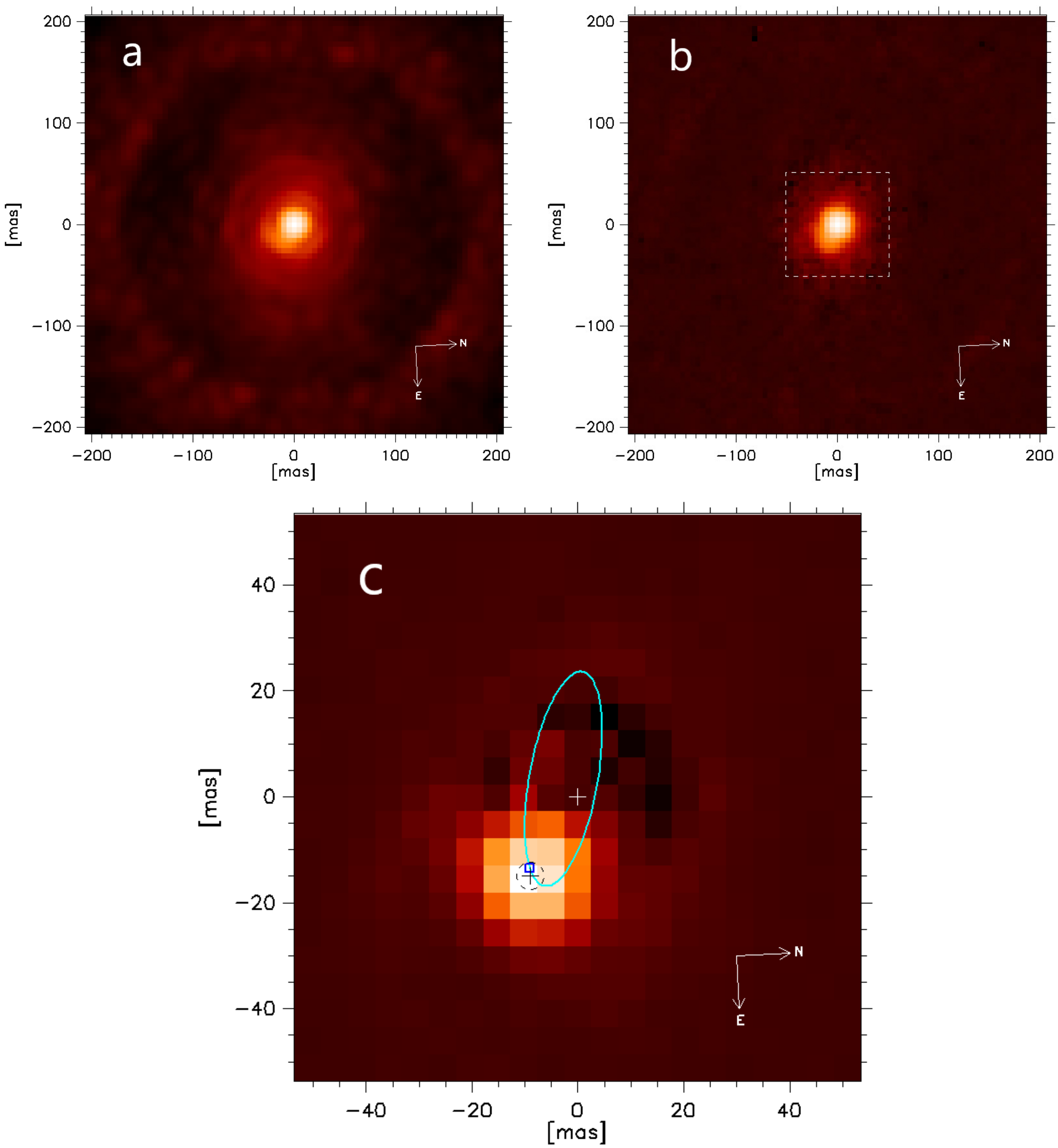

Figure 1. Forerunner-Two AO-assisted images of α And at 656 nm. **a)** Average stack of the best-quality selected frames (see text). **b)** SFI combination of the selected frames where the two components are revealed. The dashed square indicates the field displayed in the next panel. **c)** Residual SFI image after subtraction of the fitted PSF of the primary; the locations of the fitted centroids of the two stars are marked with a plus sign, while the dashed line indicates the uncertainty on the location of the secondary. The computed projected orbit of the secondary relative to the primary (Branham 2017) is also displayed, with the expected position of the companion at the moment of the observations (blue square).

with respect to the primary. This corresponds to a projected separation of about 0.5 au at the distance of the source. This measurement is in agreement within the errors with the nominal expected position derived from the orbital parameters given by Branham (2017) (position angle 126.7°, separation 16.3 mas), which were obtained combining previous spectroscopic and interferometric observations (e.g. Pan et al. 1992; Pourbaix et al. 2004). The estimated flux ratio between the components is $7.2\ ^{+1.8}_{-1.2}$ at 656 nm is in agreement with the expected value of 7.9 considering the spectral types (B8IV and A3V) and radii (2.70 $R_\odot$, 1.65 $R_\odot$) given in the literature (Ryabchikova et al. 1999). Finally, in Fig. 1 panel *c* we show the image obtained by subtracting the fitted PSF of the primary from the SFI image, to highlight the secondary component.

With an effective angular resolution of about 18 mas, the Forerunner-Two provided on α And one of the highest angular resolution images ever obtained through direct imaging, which fully confirms the huge potential of the SHARK-VIS fast-cadence approach in the visible for investigating spatial scales of the order of a few tens of mas.

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REFERENCES

Branham, R. L., Jr. 2017, MNRAS, 464, 1095

Esposito, S., Riccardi, A., Fini, L., et al. 2010, Proc. SPIE, 7736, 773609

Li Causi, G., Stangalini, M., Antoniucci, S., et al. 2017, ApJ, 849, 85

Mattioli, M., Pedichini, F., Antoniucci, S., et al. 2018, Ground-based and Airborne Instrumentation for Astronomy VII, 10702, 107024F

Pan, X., Shao, M., Colavita, M. M., et al. 1992, ApJ, 384, 624

Pedichini, F., Stangalini, M., Ambrosino, F., et al. 2017, AJ, 154, 74

Stangalini, M., Pedichini, F., Pinna, E., et al. 2017, Journal of Astronomical Telescopes, Instruments, and Systems, 3, 025001

Pourbaix, D., Tokovinin, A. A., Batten, A. H., et al. 2004, A&A, 424, 727

Ryabchikova, T. A., Malanushenko, V. P., & Adelman, S. J. 1999, A&A, 351, 963