Massive Stars Near and Far
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MAGIC Intensity Interferometer as a powerful tool to understand massive stars

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Abstract. The Intensity Interferometry technique consists of measuring the spatial coherence (visibility) of an object via its intensity fluctuations over a sufficient range of telescope separations (baselines). This allows us to study the size, shape and morphology of stars with an unprecedented resolution. Cherenkov telescopes have a set of characteristics that coincidentally allow for Intensity Interferometry observations: very large reflective surfaces, sensitivity to individual photons, temporal resolution of nanoseconds and the fact that they come in groups of several telescopes. In the recent years, the MAGIC Collaboration has developed a deadtime-free Intensity Interferometry setup for its two 17 m diameter Cherenkov telescopes that includes a 4-channel GPU-based real-time correlator, 410-430 nm filters and new ways of splitting its primary mirrors into submirrors using Active Mirror Control (AMC). With this setup, MAGIC can operate as a long-baseline optical interferometer in the baseline range 40-90 m, which translates into angular resolutions of 0.5-1 mas. Additionally, thanks to its AMC, it can simultaneously measure the zero-baseline correlation or, by splitting into submirrors, access shorter baselines under 17 m in multiple u-v plane orientations. The best candidates to observe with this technique are relatively small and bright stars, in other words, massive stars (O, B and A types). We will present the science cases that are currently being proposed for this setup, as well as the prospects for the future of the system and technique, like the possibility of large-scale implementation with CTA.

Keywords. instrumentation: interferometers, techniques: interferometric

1. Introduction

IACTs (Imaging Atmospheric Cherenkov Telescopes), are telescopes dedicated to observe Extensive Atmospheric Showers (EAS), which emit Cherenkov light. The characterization of this light allows to reconstruct and study the nature, direction and energy

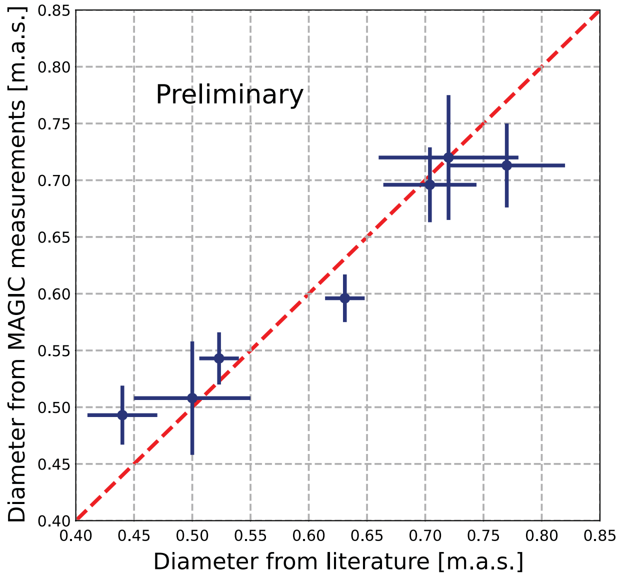

Figure 1. Measured angular diameter of 7 stars by MAGIC compared to the literature values.

of the primary of electromagnetic showers. Cherenkov telescopes are serendipitously very well suited for intensity interferometry observations: they have large reflective surfaces (to have enough statistics), are sensitive to single photo-electrons (to measure the coherence of individual photons), have nanosecond time resolution (to resolve the correlation peak) and they come in groups (several baselines).

The intensity interferometry technique is based on the Van Cittert-Zernike Theorem: a bright object of angular size θ consists of many incoherent regions that produce a pattern of size λ/θ. If the distance between telescopes 1 and 2 is $<< \lambda/\theta$, then they observe the same fluctuations.

As its name indicates, intensity interferometry makes use of the intensity of light from the source detected at different locations to measure the correlation of these fluctuations (Acciari et al. 2020). Since this measurement provides morphological information about the thermal emission of the observed source, it is a valuable tool in a broad range of stellar science cases that requires of such information: angular diameter of massive stars, limb darkening of large bright stars, fast rotators, Be stars, asteroseismology, novae and binary systems.

2. Results

To assess the performance of MAGIC's Intensity Interferometry setup (Delgado et al. 2021) we measured the spatial correlation over a range of baselines for stars with published angular sizes. The preliminary calibration of the setup already provides star diameter measurements close to literature values, as Fig. 1 shows, compatible within errors.

3. Conclusions

In the last few years it has been proved that is possible to apply the intensity interferometry technique with the MAGIC telescopes. Adding LST-1 to the MAGIC setup requires only minor modifications, and can be done as soon as in 2022. MAGIC+LST-1 setup can be further extended to future LSTs, providing large boost in performance, due to linear improvement of the sensitivity with the number of telescopes and mirror area.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1743921322002290.

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