HIGH ANGULAR RESOLUTION IMAGER FOR SOAR

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1 Context

Imaging and spectroscopy of faint sources is done today at the angular resolution of adaptive optics (AO) in the infra-red and at the resolution of the 2.4-m Hubble Space Telescope in the visible. Reaching the diffraction limit in the visible from the ground for progressively fainter sources continues to be an important goal for astronomy. The 4.2-m SOAR telescope is from the outset aimed at reaching the sharpest images, distinguishing itself in this respect from the competing mid-size telescope.

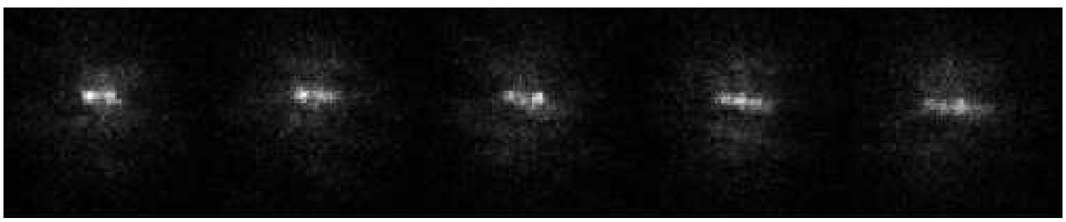

Figure 1: Series of 5 consequtive frames of a single star HIP 6380 in the I band corrected by SAM in the NGS mode (November 2010). The field size and distance between images is $1''$. Prominent diffraction-limited speckle dominates the image core.

The SOAR Adaptive Module (SAM) will soon deliver sharpened images, improving the natural seeing in a $3'$ field [5]. The technical High-Resolution Camera (HRCam) developed as part of SAM project reaches the diffraction-limited resolution (30 mas) on bright stars by using short exosures and speckle-interferometry image processing. This instrument has already produced several science papers, e.g. [6]. Combination of HRCam with AO correction holds a great promise [7], see Fig. 1. However, in the near future, when the HRCam on SAM will be replaced by other visitor instruments (nominally SIFS), this capacity will no longer be available.

Here we propose to build a simple, but more performant High Angular Resolution Imager (HARI) that will occupy one of the bent-Cassegrain ports of SOAR. This instrument will enable permanent access to diffraction-limited imagery of relatively bright (to $V \sim 15$) stars and their vicinities, including "lucky" imaging [1, 3, 4]. It will also serve as a platform for future developments. A unique feature of the proposed instrument will be a combination of adaptive optics with rapid imagery and post-processing.

2 Science goals

A non-exhaustive list of potential science programs for the HARI includes:

- Followup of close nearby binaries and determination of their orbits, leading to mass measurement (including pre-main-sequence stars), statistics of orbital elements, dynamics of multiple systems, etc.
- Surveys of various stellar polulations for binarity delivering observational constraints on star formation.
- Optical imaging of solar-system objects (planetary satellites, asteroids), see e.g. [2].
- Studies of dense stellar aggregates (globular clusters, young groups like R 136a).
- Resolved emission details around young stars (jets, disks)

Binary stars will probably be among the most frequent targets. Apart from the study of orbits and masses (which is still one of the fundamentals of astronomy), there is a rich and diverse science related to objects of particular interest, binary statistics, dynamics of high-order multiples. Current interest in exo-planets and nearby stars adds to the need of discovering and monitoring nearby multiple systems.

The science use of HARI will strongly depend on its magnitude limit. We foresee a tradeoff between resolution and sensitivity. The highest resolution will probably be achieved on-axis for stars with $V \leq 12^m$. Fainter targets will be observed with longer exposures and in wider bandpass. In this case, the AO loop will work very slowly, correcting only static aberrations and dome seeing, but still delivering truly seeing-limited images. Further resolution enhancement will be achieved in post-processing by selection of the sharpest frames ("lucky" technique) and re-centering. A relatively wide field of HARI ($30''$) will give access to many of targets where a sufficiently bright star required for these image-sharpening methods is present. There is a possibility of upgrading HARI to an imaging polarimeter or doing other experiments such as non-redundant pupil masking.

3 Instrument concept

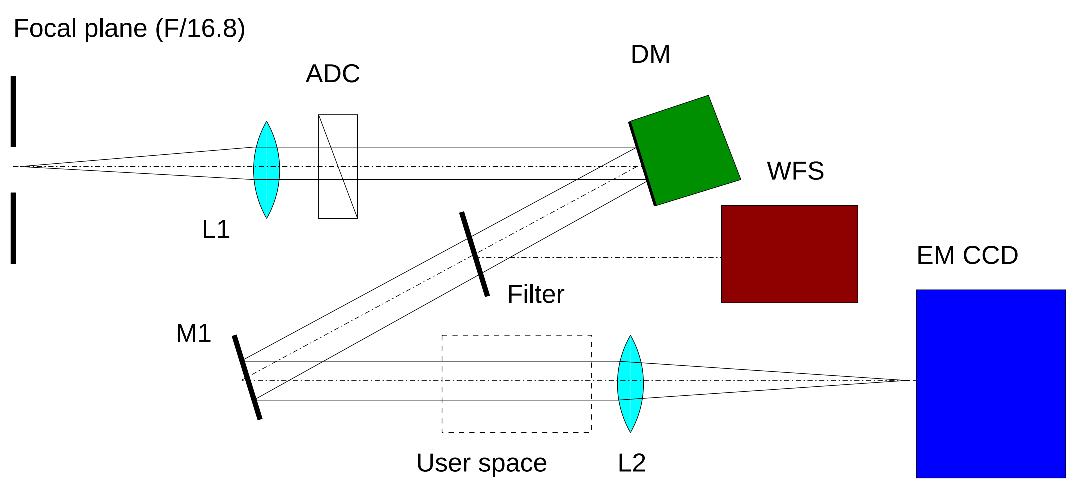

Figure 2: Conceptual disgram of HARI

The instrument will use a modern EM CCD detector with high quantum efficiency and a large number of pixels. For example, a 2Kx2K detector with 15-mas pixels (Nyquist-sampling) will cover a field of 30″. Suitable pixel scale will be achieved by a simple refractive re-imaging system consisting of two achromatic lenses.

The collimated beam between the re-imaging lenses L1 and L2 (Fig. 2) will contain the atmospheric dispersion corrector ADC (a pair of Risley prisms), a turbulence corrector (small MEMS deformable mirror, DM), and a filter or dichroic on a wheel. The interference filter transmits the science wavelength to the detector, reflecting the remaining light towards the wave-front sensor (WFS). Before the science beam is focused on the detector by L2, additional optical elements can be placed in the collimated beam (e.g. a narrow-band filter, polarization modulator or pupil mask).

The instrument will be located at the bent-Cassegrain port of SOAR. It will not rotate (the field rotation will be compensated in the data co-addition from multiple short exposures). The collimated beam size will be small (e.g. 5 mm), leading to small overall dimensions (say 0.5 m). Mechanically, the instrument will be a box with various optical elements mounted inside and detectors outside. The instrument will have only two motorized motions: filter wheel and ADC.

4 Implementation

The HARI can be constructed rapidly and economically by using, whenever possible, commercial components or copies of existing solutions. For example, the MEMS DM can be procured from ThorLabs, the EM CCD can be a copy of the BTFI detector, the AO software – an adaptation from SAM.

The instrument is highly modular. It will be constructed in several stages. First, the box, optics and detector system will be implemented, permitting a rapid start of observations without AO correction (the DM is replaced then by a flat miror). In parallel, the AO system is developed and tested in the laboratory, then installed in HARI. As a rough estimate HARI, can be constructed in 2-3 years at a cost of 0.5 M$.

References

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