AIRY: Astronomical Image Restoration in interferometrY

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Abstract. AIRY is a modular software package designed to simulate optical and near-infrared interferometric observations and/or to perform subsequent image restoration/deconvolution. It is written in IDL and has been designed to be used together with the CAOS Application Builder, version 2.0 or higher. AIRY can be applied to a wide range of imaging problems. We will present in particular an application to the case of interferometric imaging with the Large Binocular Telescope, in which we simulate the observation and scientific interpretation of a synthetic star cluster in the near-infrared.
(related WEB page: `http://dirac.disi.unige.it`)

1. Introduction

AIRY is the acronym describing the activity of a group of astronomers and mathematicians from various Italian institutions (see the WEB page indicated above). The aim of the collaboration is to develop methods and software for the restoration of interferometric images, with application to the Large Binocular Telescope (LBT). One of the first results is the package AIRY, IDL-based and CAOS-compatible (Fini *et al.* 2001). AIRY is designed to simulate optical and near-infrared interferometric observations and/or to perform subsequent image restoration/deconvolution. It consists of a set of specific modules which are listed and briefly presented in section 2. The package also includes a library of ideal and Adaptive Optics (AO) corrected LBT point-spread functions (PSFs). Details can be found in Carbillet *et al.* (2001). An interesting feature of AIRY is its multiple deconvolution capability, well suited for the LBT case. In the current version the method implemented is the so-called *Ordered Subsets - Expectation Maximization* (OS-EM) algorithm (Bertero & Boccacci, 2000a). As an example of application we present in section 3. a simulated LBT observation together with a scientific interpretation of the results.

2. The modules of AIRY Simulation Package

Table 1 shows a complete list, together with a very brief description, of the modules of the current version of the AIRY Simulation Package.

Table 1. Descriptive list of the modules of AIRY Simulation Package.

Module	Purpose
Data simulation modules	
`OBJ - OBJect definition`	-to define the object characteristics among several object types (binary object, open cluster, planetary nebulae, SN remnant, spiral galaxy, YSOs, stellar surface, user-defined)
`CNV - object-PSF CoNVolution`	-to perform convolution
`ADN - ADd Noise to image`	-to add the noise contributions
Data processing modules	
`PRE - PRE-processing`	-to perform image pre-processing
`DEC - DEConvolution process`	-to perform deconvolution (*Ordered Subsets-Expectation Maximization* method)
Data analysis modules	
`ANB - ANalysis of Binary`	-to analyse reconstructed images of binary objects
`FSM - Find Star Module`	-to detect stars in the reconstructed images
Other modules and utilities	
`RFT - Read FiTs file format`	-to read FITS images
`WFT - Write FiTs file format`	-to write FITS images
`RSC - Restore im. Struct. Cubes`	-to restore image structure cubes (XDR format or FITS format)
`SIM - Save IMage struct.`	-to save image structure cubes (XDR format or FITS format)
`DIS - DISplay image`	-to display images

Figure 1 shows an example of simulation that can be built with the AIRY Simulation Package. This simulation is essentially composed of three parts. The

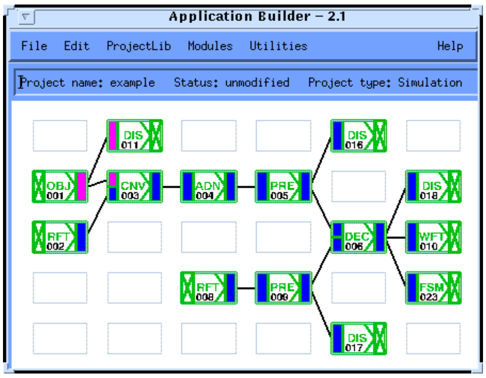

Figure 1. Example of worksheet of a typical simulation.

first part models the observed data by convolving an object map (supposed here to be a stellar cluster) of given characteristics with a set of PSFs (object-PSFs), extracted for example from the library. The different noise contributions are then added. The second part is the restoration of the observed data set by multiple deconvolution with another set of PSFs (reference-PSFs), after a pre-processing stage. The third part permits the analysis of the deconvolved image, and saves it.

Note that the modular structure of AIRY also allows to use the package for improving real AO data by removing part of the AO-correction residual, or/and to produce images from real interferometric data.

3. Example of application: Scientific analysis of a simulated star cluster observed with the Large Binocular Telescope

The goal is to simulate high-resolution interferometric observations of a scientific object of interest with LBT and to retrieve the scientific parameters of this object after the image restoration process. We have considered a star cluster composed of 1898 stars with the following characteristics: age 4.0 Gyr, metallicity Z=0.008, distance modulus=19 ($\simeq$ 63 kpc), reddening=0, extension field=$10.24'' \times 10.24''$.

Three object maps (2048×2048 pixels) were modeled in J, H and K bands. The resulting magnitude ranges were respectively 14.01-24.22, 13.25-23.63 and 12.89-23.56. The worksheet of this simulation is similar to that presented in Fig. 1 for each band. We have simulated observations at 3 parallactic angles (0°, 60° and 120°) for each band, and with 2000 s integration time for each parallactic angle. PSFs were assumed ideal (coherence, cophasage, no aberrations) for both the reference and the object-PSFs. Multiple deconvolution was carried out for each band using 100 iterations of the *OS-EM algorithm* (see Bertero & Boccacci 2000a, B&B 2000b, Bertero *et al.* 2000). Detection and photometry on the restored frames were performed using Daophot, with a 25-sigma detection threshold and a 3 pixels (15 mas) aperture photometry diameter.

The Color-Magnitude Diagram (CMD) of the star cluster in the plane H vs (J-H) is shown in Fig. 2. Detected stars are marked with squares and isochrones corresponding to different ages and metallicity values are superimposed. From

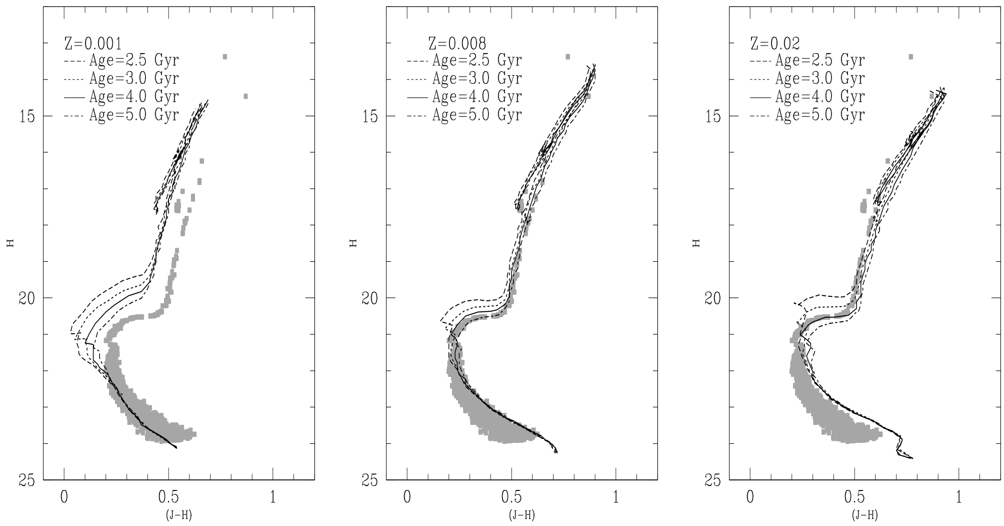

Figure 2. CMD of the star cluster in the plane H vs (J-H). Detected stars are marked with squares and isochrones corresponding to different age and for metallicity Z=0.001 (left), Z=0.008 (center) and Z=0.02 (right) are superimposed.

a first visual inspection, we can derive that Z$\simeq$0.008 and the age is 4.0-5.0 Gyr, that is in good agreement with the input parameters.

References

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