DEVELOPMENT STATUS OF THE DOTIFS DATA SIMULATOR AND THE REDUCTION PACKAGE

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ABSTRACT

A data simulator and reduction package for the Devasthal Optical Telescope Integral Field Spectrograph (DOTIFS) has been developed. Since data reduction for the Integral Field Spectrograph (IFS) requires complicated procedures due to the complex nature of the integral spectrograph, common reduction procedures are usually not directly applicable for such an instrument. Therefore, the development of an optimized package for the DOTIFS is required. The data simulator observes artificial object and simulates CCD images for the instrument considering various effects; e.g. atmosphere, sky background, transmission, spectrograph optics aberration, and detector noise. The data reduction package has been developed based on the outcomes from the DOTIFS data simulator. The reduction package includes the entire processes for the reduction; pre-processing, flat-fielding, and sky subtraction. It generates 3D data cubes as a final product, which users can use for science directly.

Key words: Data simulator, Integral Field Unit, Optical spectrograph, Astronomical instrumentation

1. INTRODUCTION

DOTIFS (Chung 2014) is a new multi-object integral field spectrograph planned to be designed and built by the Inter-University Center for Astronomy and Astrophysics, Pune, India, for the Cassegrain side port of the 3.6m Devasthal Optical Telescope (Sagar 2012) and is being constructed by the Aryabhatta Research Institute of Observational Sciences, Nainital, India. It has 16 integral field units to sample a two dimensional area of the sky, with each unit covering an 8.7” × 7.4” field of view with 144 spaxel elements, sampling at 0.8” per hexagonal aperture. Eight identical spectrographs disperse light from the IFUs, (Integral Field Units) delivered by optical fibers, and produce 2,304 R ∼1800 spectra over a 370-740nm wavelength range with a single exposure. Due to the complex nature of the data, fiber-fed integral field spectrographs require specific data reduction software for each instrument, instead of generalized routines. To develop the software, an actual CCD spectral image is usually required. However, a real CCD image is not available until the instrument is built and commissioned. Since developing a data reduction software is quite time consuming, it has to be done simultaneously with building the instrument to minimize the time gap. For this, a data simulator is essential for producing artificial CCD images, which will be used instead of real ones. The data simulator performs a virtual observation and generates spectral data as would be recorded on the CCD by the real instrument. Various instrumental and other effects are involved in making the simulated data as close as possible to real data: e.g. atmosphere, sky background, transmission, spectrograph optical aberration, and detector noise. In this proceeding, we briefly describe how the data simulator works and show the development status of the data reduction software.

2. SIMULATOR STRUCTURE

2.1. Modeling Fiber Image from Spectrograph Optics

Due to optical aberrations, the image of a fiber on the CCD varies depending on the wavelength and position on the slit. These images can be simulated by ZEMAX
and exported in numerical form for use with external software. To save time and avoid inefficiency, fiber images only at specific locations on a grid are pre-generated and saved for use in the data simulator. Other optical effects such as field distortion are also included. To account for field distortion effects, fiber tramlines on the CCD are calculated by ZEMAX. Each of these are then fitted with a 4th order polynomial function and saved. These polynomial functions are then used to determine the location of the chief ray for each fiber and at each wavelength.

2.2. Generating Input Spectra through Virtual Observation
To start with, spectra of an actual object which was observed by the CALIFA survey was used (Sanchez 2012). These spectra were re-sampled with DOTIFS IFU specifications. PINGSOFT software was used for visualization. To perform virtual observations, DOTIFS IFU is assumed to be positioned at a specific point on the CALIFA survey object. By summing spectra which fall on each DOTIFS microlens, we can obtain 144 resampled spectra. Since a single DOTIFS spectrograph accommodates fibers from two IFUs, the resampling was performed at two different locations on the observed object. In addition, other type of inputs, such flat field spectra or calibration (arc lamp) spectra can also be used as an input for the simulator.

2.3. Simulating CCD Images by Convolving Fiber Image Models and Input Spectra
Light from each fiber at each specific wavelength forms fiber images on the CCD. The sum of all fiber images on the focal plane results in the final spectra. The simulator accomplishes the same result by convolving each fiber tramline with the corresponding fiber image at each point on the tramline. Since the CCD x-y plane corresponds to the wavelength-fiber plane, wavelength and fiber number determine which fiber image shape and intensity will be used at a specific location on the CCD. Fiber images at different location are obtained by 2D interpolation of the adjacent 4 locations. The intensity of the fiber image is determined by the flux of input spectra at corresponding wavelengths. Other observational variables such as sky transmission, instrument transmission, exposure time, airmass, and moon phase are included, and the final flux is converted into photon counts. In addition, detector properties such as photon noise, dark noise, readout noise and CCD gain are also incorporated to construct the final CCD image.

3. DATA REDUCTION SOFTWARE
The data reduction package for DOTIFS is being developed specifically to reduce the output from the DOTIFS data simulator. It will include all the steps for reduction; e.g. pre-processing, flat-fielding, and sky subtraction, while generating a 3D cube data as the final product, which users can use for science. Since developing the entire reduction package from the beginning requires a large amount of time and effort, we use one of the most generalized IFS data reduction software, P3D (Sandin 2010) as a starting point as well as a reference. Details of the reduction software will be presented in future when it is completed.

4. SUMMARY
The DOTIFS data simulator has been developed for the future development of data reduction software. The simulator generates expected CCD images for the DOTIFS spectrograph. An output image shows spectra from each fiber, as well as effects of optics such as aberration and distortion. The output will serve as input data for the development of data reduction software, until an actual CCD image is obtained.

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