The Infrared Imaging Spectrograph (IRIS) for TMT: Final Design Development of the Data Reduction System

Arun Surya; Andrea Zonca; Nils-Erik Rundquist; Shelley Wright ; Gregory L. Walth ; David Andersen; Edward Chapin; Eric Chisholm; Tuan Do; Jennifer Dunn; Kim Gillies; Yutaka Hayano; Chris Johnson; Renate Kupke; James Larkin; Takashi Nakamoto; Reed Riddle; Roger Smith; Ryuji Suzuki; Ji Man Sohn; Robert Weber; Jason Weiss; Kai Zhang

Introduction

IRIS (Infrared Imaging Spectrograph) is the near-infrared (0.81-2.4 microns) diffraction-limited imager and integral field spectrograph (IFS) designed for the Thirty Meter Telescope (TMT) and the Narrow-Field Infrared Adaptive Optics System (NFIRAOS). The imager will have a 34 arcsec x 34 arcsec field of view with 4 milliarcsecond (mas) sampling. The IFS consists of a lenslet array and a slicer, enabling four plate scales from 4 mas to 50 mas, with multiple gratings and filters. The IRIS DRS is developed in Python with the software architecture based on the James Webb Space Telescope science calibration pipeline stpipe. We are developing a library of algorithms as individual Python classes that can be configured independently and bundled into pipelines. The IRIS DRS will interface with the TMT observatory software and will operate in real-time and as a stand-alone public package for offline reduction. The IRIS DRS also includes a C library for readout processing that is used for both real-time processing and post-processing.

DRS Architecture

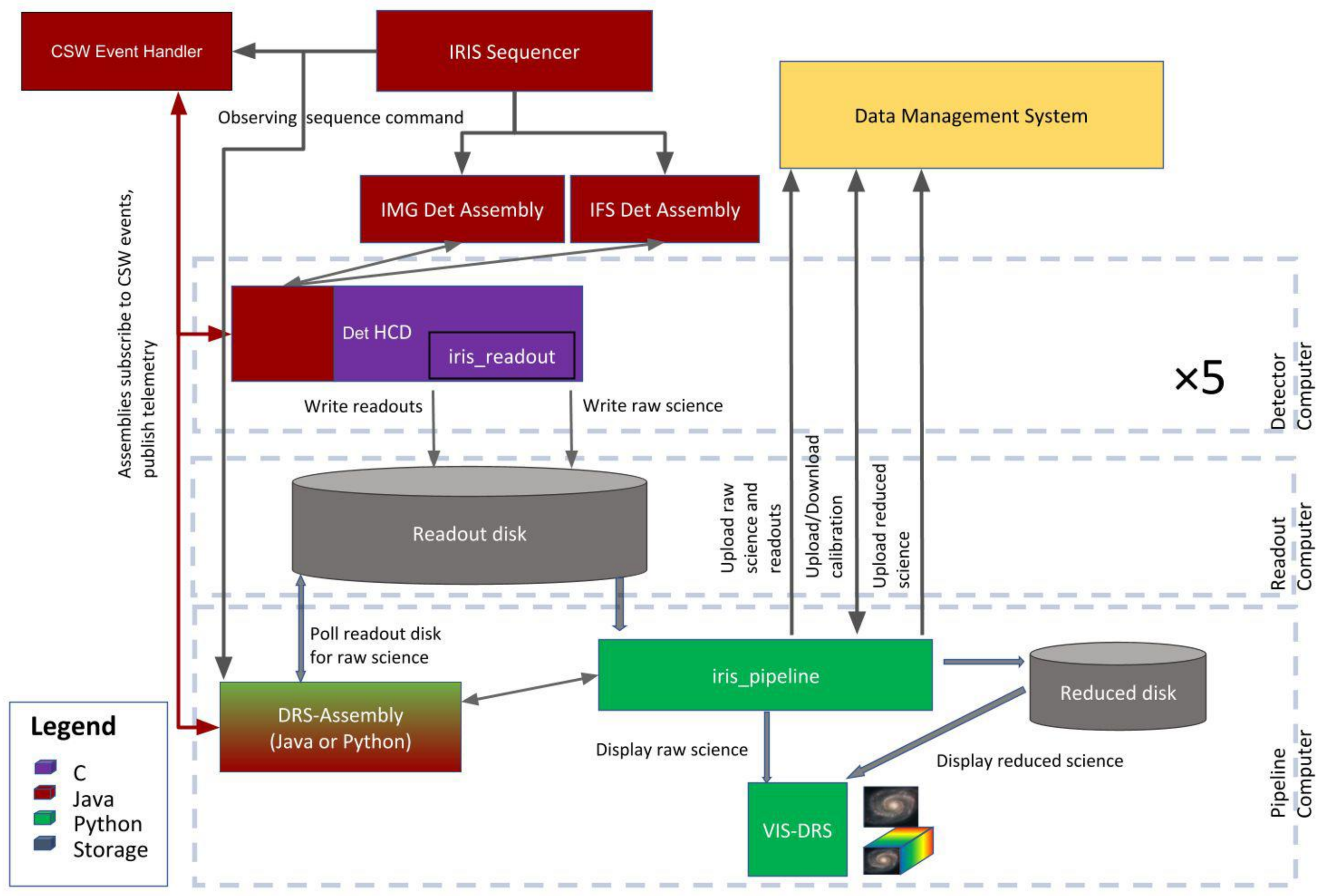

Fig.1 Architecture of the DRS-Assembly and the reduction pipelines integrated into the Observatory Software for online processing on site. The different colours are used to show the development platforms. The IRIS sequencer shares observing configuration and notifications to the DRS-Assembly. The detector software writes the readouts and processed raw frames in to the disk. DRS-Assembly invokes instances of iris_pipeline to process the raw frames. iris_pipeline also uses the interface with DMS to access calibration files and to store DRS data products. The DRS visualisation tools are used for astronomers to view the reduced and raw frames real-time during observations.

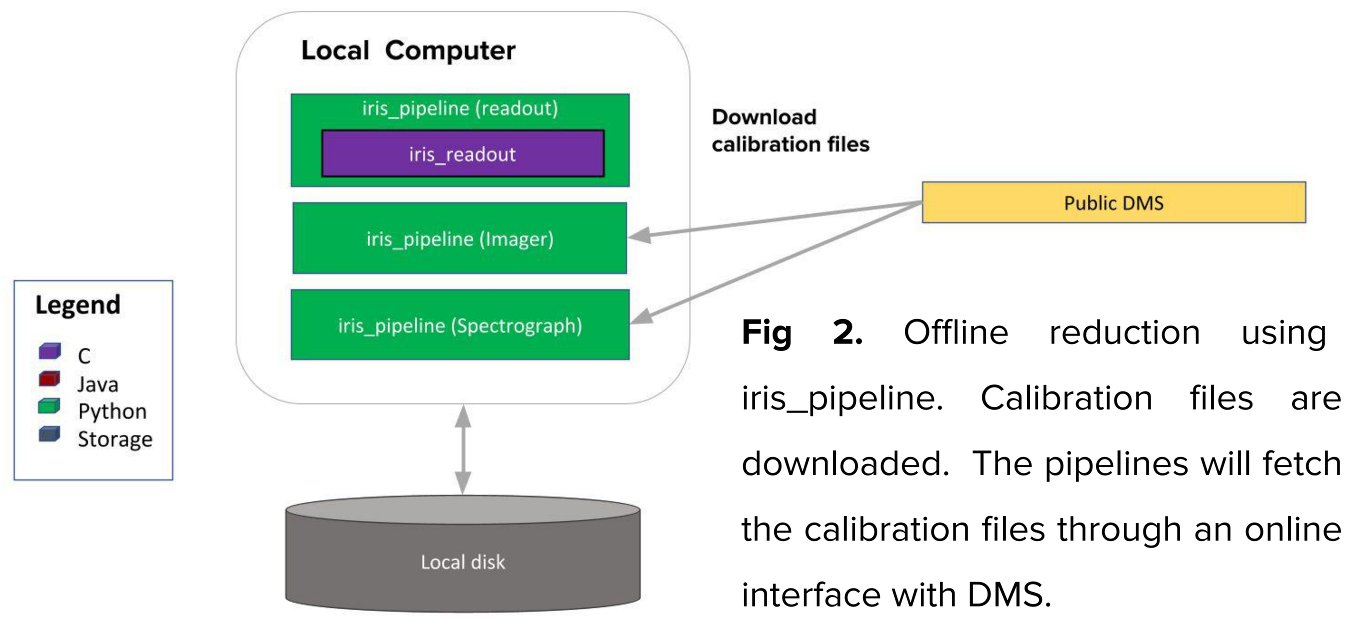

Fig 2. Offline reduction using iris_pipeline. Calibration files are downloaded. The pipelines will fetch the calibration files through an online interface with DMS.

iris_pipeline and Data Products

iris_pipeline is the main pipeline software of DRS and will be available to the astronomers to do offline reduction of IRIS data. Together with DRS-VIS, iris_pipeline can be used by astronomers to process and visualize IRIS data. iris_pipeline can be visualized as a collection of several different pipelines working on different levels of data processing. Primarily data products processed by IRIS DRS are of three types corresponding to the levels of processing. Readout File, Raw Science Frame, Processed Frame.

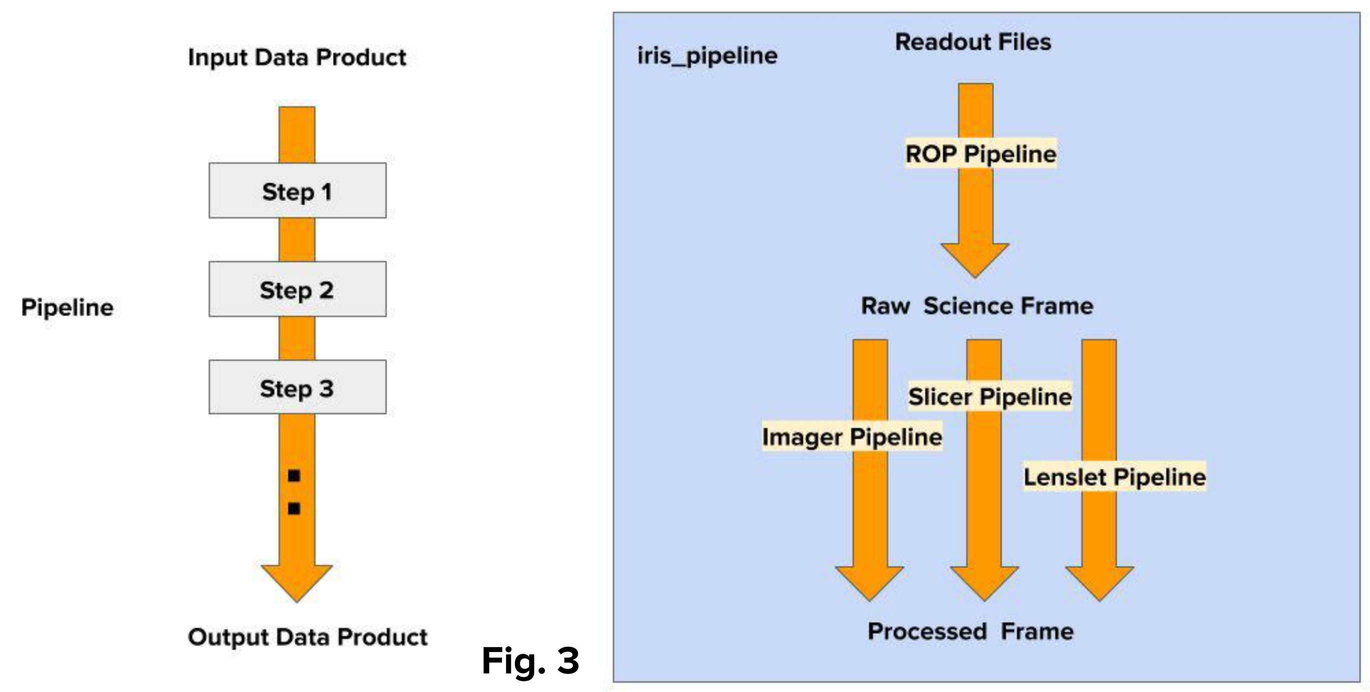

Fig. 3

IRIS Simulator

IRIS simulator has been extremely useful to determine instrument sensitivities and explore a large number of science cases and technical performances of the instrument. The simulator uses realistic noise and background models together with simulated Point Spread Functions (PSF) from TMT and NFIRAOS. We have developed new routines in the simulator that allows us to simulate raw data from the imager and the IFS. We use these simulated data products to develop iris_pipeline routines.

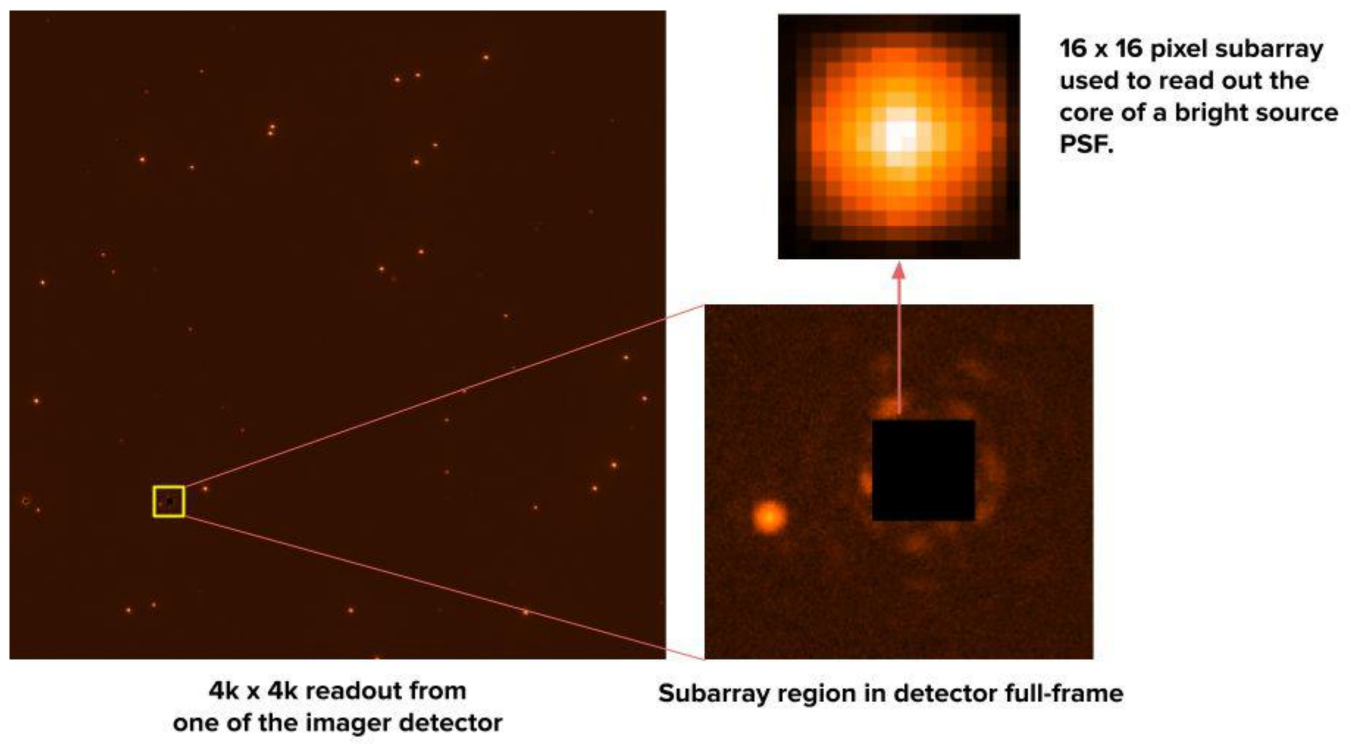

Fig 4. Simulated subarray and full frame of one of the imager detector with readout simulator. Subarrays are sub-regions that can be readout faster than the entire array. This gives the ability to read out bright sources in the field that will saturate faster.

IFS Raw Spectra simulations

The lenslet IFS finest plate scale of 4 mas/spaxel aims to preserve the superb image quality supplied by the adaptive optics system. The lenslet array is designed with a pitch of 350 microns and creates an array of micro pupil images that will be dispersed by the spectrograph. These micro pupil images are dominated by diffraction effects and create spots larger than the geometric pupil size estimated by ray tracing. These effects are modeled using physical optics propagation using Zemax.

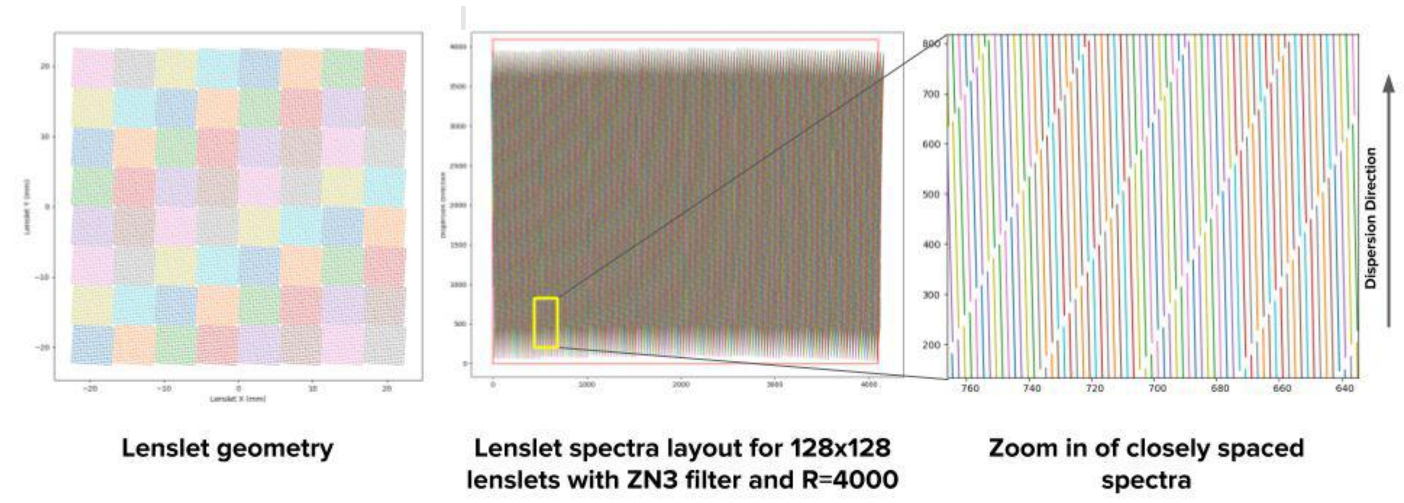

Fig 5. Spectral layout for the lenslet IFS. The simulation used ZN3 filter (0.89-0.94 microns) with R=4000 with 4mas spatial scale. [Left] Geometry of the 128 x 128 lenslet array used in IRIS. The individual 16 x 16 groups are staggered from each other and the lenslet array is tilted by a small angle to avoid the overlapping of spectra from adjoining lenslets in the same row. In the figure 16 x16 lenslet groups are coloured separately to visualize the staggered pattern of the array. [Center] The spectral layout of lenslet. [Right] Zoomed in view of the closely separated spectra from the lenslet IFS. Spectra from different lenslets are coloured differently. The spectra are separated by 30 microns on the detector plane.

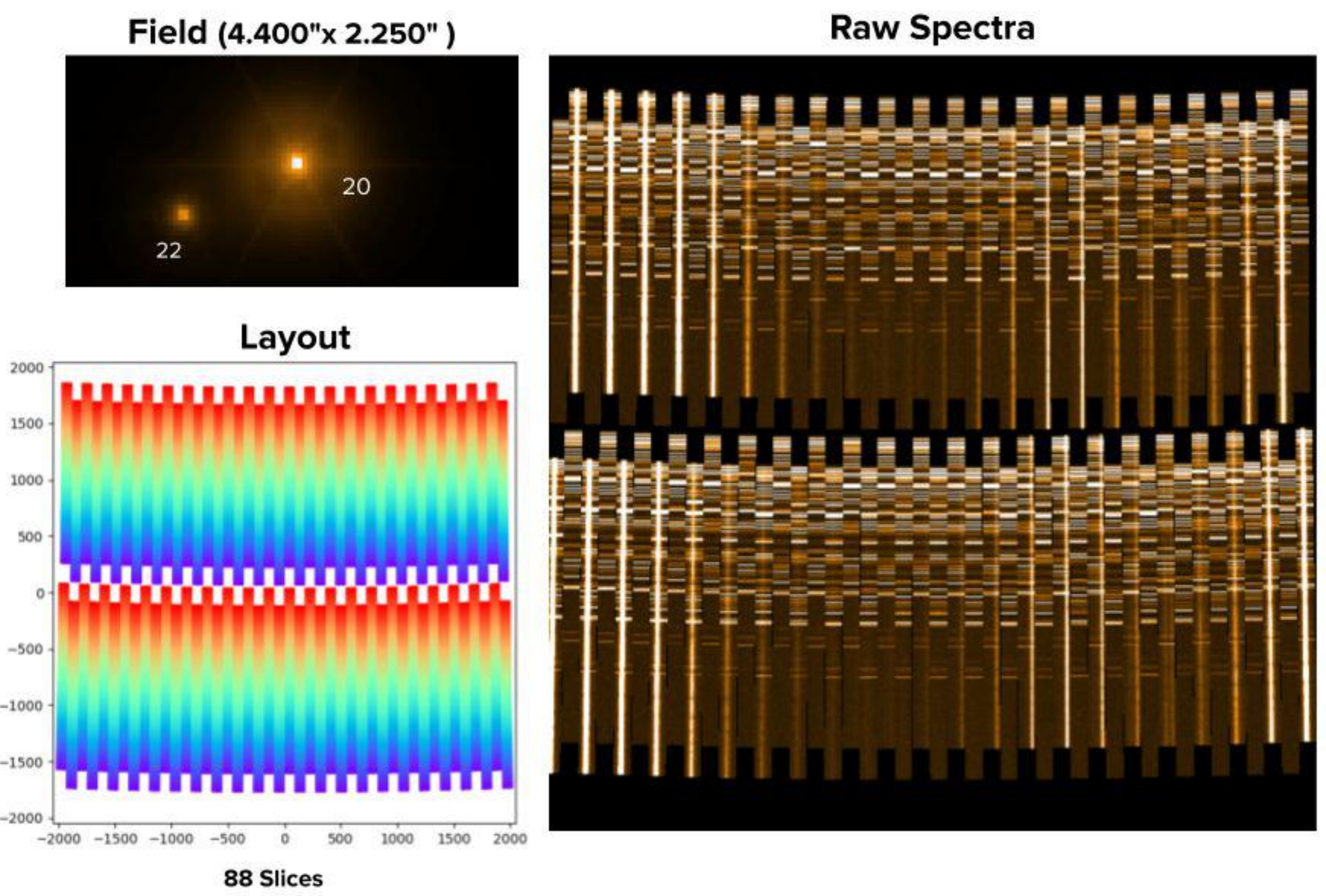

Fig 6. Raw spectra simulation of the slicer IFS. The figure shows the simulation of a binary star observed using the slicer IFS. The simulation was done for Zbb filter (0.81-0.99 microns) with R=4000 at 50 mas scale of the slicer. The field and the spectral layout of the slicer used for the simulations is shown on the left. The raw spectra simulated is shown on the right.

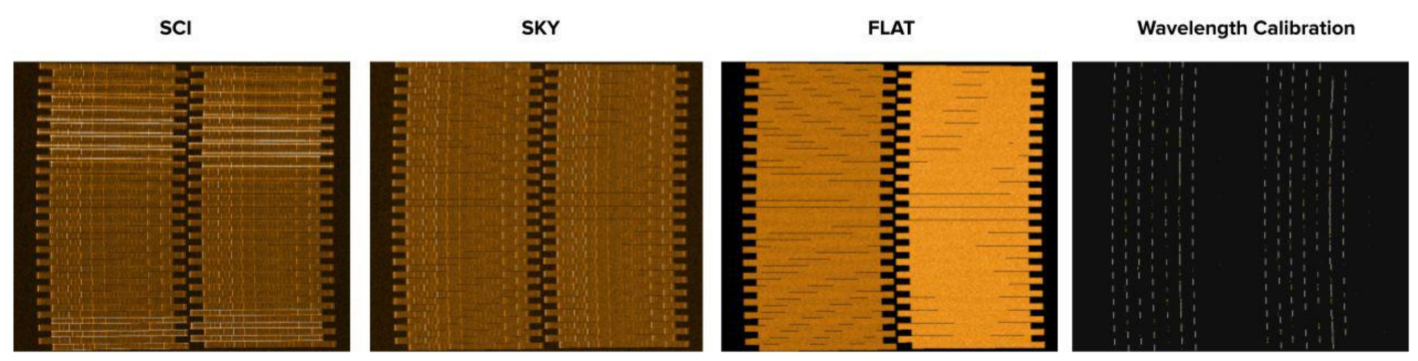

Fig 7. Simulated raw frames of slicer IFS including science and calibration frames. Currently the simulator can generate science frames and calibration frames including sky, flat and lamp spectra for wavelength calibration.

Links

1. Current development version of iris_pipeline and documentation https://oirlab.github.io/iris-pipeline/
2. IRIS Exposure Time Calculator https://www.tmt.org/etc/iris

CASS CENTER FOR ASTROPHYSICS AND SPACE SCIENCES

TMT INTERNATIONAL OBSERVATORY

IRIS

The TMT Project gratefully acknowledges the support of the TMT collaborating institutions. They are the California Institute of Technology, the University of California, the National Astronomical Observatory of Japan, the National Astronomical Observatories of China and their consortium partners, the Department of Science and Technology of India and their supported institutes, and the National Research Council of Canada. This work was supported as well by the Gordon and Betty Moore Foundation, the Canada Foundation for Innovation, the Ontario Ministry of Research and Innovation, the Natural Sciences and Engineering Research Council of Canada, the British Columbia Knowledge Development Fund, the Association of Canadian Universities for Research in Astronomy (ACURA), the Association of Universities for Research in Astronomy (AURA), the U.S. National Science Foundation, the National Institutes of Natural Sciences of Japan, and the Department of Atomic Energy of India.