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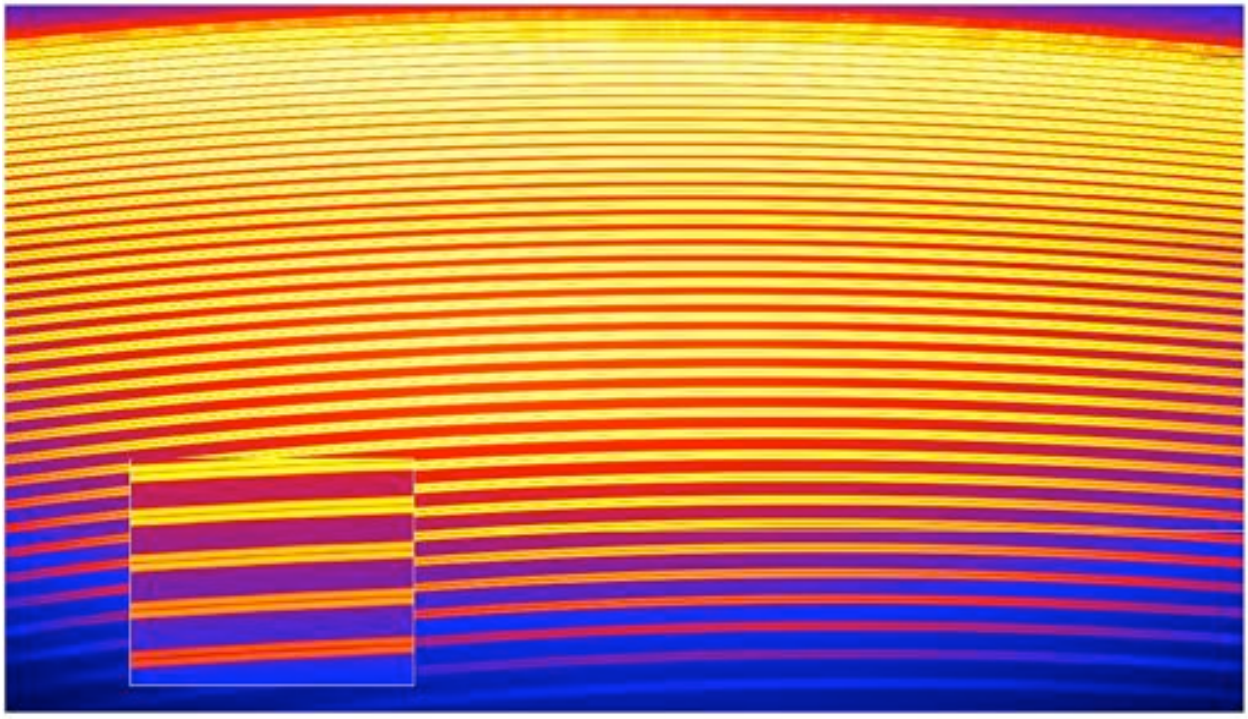
FINAL OPERA CORE REDUCTION PIPE-LINE PROJECT SCOPE



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Waimea, HI October 2010

Contents

I. Introduction

OPERA (Open-source Pipeline for Espadons Reduction and Analysis) is an open-source collaborative software reduction pipeline for ESPaDOnS data. ESPaDOnS is a bench-mounted high-resolution echelle spectrograph and spectro-polarimeter which was designed to obtain a complete optical spectrum (from 370 to 1,050 nm) in a single exposure with a mode-dependent resolving power between 68,000 and 81,000. Each exposure contains 40 orders which are curved; the image produced by the slicer (pseudo-slit) has a shape which is tilted with respect to rows.

This document outlines the scope of the OPERA project.

II. Rationale

The development of OPERA was requested by the astronomy community in order to have more transparency and flexibility in the reduction process. By making the pipeline sources freely available users can modify and use the core reduction pipeline and extend it as they wish. At the same time CFHT benefits in being able to make use of software available in the astronomy community to create the pipeline.

ESPaDOnS will continue to be one of the main instruments at CFHT at least for the next five years and it must continue to evolve. OPERA is an open source software project that will be managed by the CFHT team and will be developed as a collaborative work. Our main users, the scientists, are welcome to use OPERA and also to give their own input for further development and improvement. The open-source nature of OPERA also permits other instruments and telescopes to be part of the project.

III. Terminology

It will be beneficial to define the meaning of certain terms that we will use consistently throughout this document.

1. **Detrending** - *Detrending* means removal of instrument signature from the raw data, It consists of the following steps:

   - bias subtraction
   - bad pixel masking
   - cosmic ray rejection
   - geometric calibrations: finding and tracking spectral orders, locating the "slit" and characterizing its shape
   - flat-fielding
   - extraction of (intensity) spectra, for all 3 Observing Modes (Star Only, Star+Sky, Polarization)
   - use of a flat field response (solar spectrum) (optional)
   - wavelength calibration based on comparison exposures
   - correcting wavelengths based on telluric lines (optional)
   - stitching orders together

2. **OPERA Core Reduction** - *OPERA Core Reduction* extends *Detrending* steps to produce *reduction products* which will be the products of the CFHT-based pipeline for OLAPA. The products will be released by CFHT and as such **must** be FITS format files. *OPERA Core Reduction* consists of the following steps:

   - detrending steps
   - normalize the continuum (optional)

- calculation of polarized spectra for the Polarization mode with continuum polarization subtracted
- calculation of null polarization spectra in polar mode
- sky subtraction for the Star+Sky observing mode
- calculation of error bar quality assessment
- provide spectral resolution and S/N quality assessment for each order

3. **OPERA Analysis and Post Reduction** - *OPERA Analysis and Post Reduction* steps are optional and open ended. The pipeline must be flexible enough to add *OPERA Analysis* steps albeit with an undefined amount of effort. The *OPERA Analysis Products* are not a part of the CFHT-based pipeline with the exception that CFHT will create a Distribution Post Reduction module.
4. **OPERA Core Reduction Products** - *OPERA* Core*Reduction Products* are the output files of the *Core Reduction* steps. The files are in FITS format and will be released by CFHT.
5. **OPERA Analysis and Post Reduction Products** - *OPERA Analysis and Post Reduction Products* are the output files of the optional *OPERA Analysis* steps. The files may be in formats other than FITS format and will be not released by CFHT.
6. **Open-Source** - Open source is taken to mean that the source code is available for use and modification by anyone under the terms of the included license.

IV.OPERA

1. Open Source Collaboration

OPERA is an open source and collaborative software project. It is an image reduction pipeline for ESPaDOnS data. It consists of documentation, infrastructure for collaboration, a software harness, software calibration and reduction modules, software libraries and test data and harness. The software and documentation will be hosted on SourceForge. The project will be managed by CFHT personnel, with contributions from the scientific community. CFHT is responsible for ensuring the the OPERA Core Reduction pipeline completes successfully and on time.

2. License

The prevailing license of a software contribution is the license of the institution providing the software. OPERA will have a blanket disclaimer that ensures that a license of any single module may not infringe on any other module that is part of OPERA.

3. Objectives

OPERA is an open source collaborative project that anyone may use and modify. As such it is intended to be widely distributable and freely available

to other instruments and facilities. Basing development on collaboration allows the best talent to contribute to the overall quality of the results. OPERA will produce at least those reduction products currently provided by Libre-Esprit for the instruments identified in 4) below.

4. Instruments

OPERA Core Reduction will use data taken from the ESPaDOnS EEV1 device and the OLAPA device in either one or two amplifier instrument device modes. The instrument device modes may be mixed in a given night. OPERA will associate calibrations with data taken in the same instrument device mode. OPERA will reduce spectrographic and polarimetric data. Sufficient calibration data (flats, biases, etc) must be taken in order to reduce the observational data.

OPERA provides an open source framework that should not preclude use by other instruments. As such all parameterization should be localized to header files or definition files. Interfaces to data should be done through a *parameter access layer* which may resolve to database or other data sources. The harness should be configurable so that reduction modules may be added or inserted reasonably easily.

5. Pipeline Scope

The *OPERA Core Reduction* pipeline will have several phases.

1) It will create the associations between calibrations and object images

2) It will support the creation of master calibrations from calibration images.

3) It will support the reduction observational data to spectra.

4) It will also have a post verification phase which will test the completeness and correctness of the products.

5) It will produce a report log of the reduction.

6) It will produce quality assessment metics.

The *OPERA Analysis Reduction* phase may have:

1) a simulation phase,

2) open ended Analysis modules such as Radial Velocity calculations, LSD support, etc and To Be Described.

6. *OPERA Core Reduction Products*

The *OPERA Core Reduction* pipeline will produce at least the products available now from the upena pipeline. All final products will be in FITS format suitable for release by CFHT. As such OPERA will produce at minimum

1) intensity spectra

2) polarimetry spectra

3) normalized and un-normalized data

4) with and without autowave correction.

5) Error bars

6) Check spectrum.

7) Quality assessment metrics

7. OPERA Harness

The harness is a separate piece of software which controls and directs the execution of reduction modules. The harness may support parallel module execution and may support module execution on multiple machines. Nothing in the harness or modules should preclude parallel operation.

8. Graphical Interface

There is no plan to create a graphical interface for either viewing or controlling the *OPERA Core Reduction* pipeline.

9. Parameterization

OPERA pipeline execution should be parameterized, based on instrument, detector and other characteristics. The parameters may be stored in a data table or database, but use of a database is not mandatory. Access to parameters should be through a *parameter access layer* provided as a software library.

10. Software Modules and Libraries

A *Software Module* is an independent and complete software program that may be executed by the harness. A *Software Library* is common code that may be included in a module, by cannot be executed by itself. Software modules and libraries will be created in the course of building OPERA. At minimum the following libraries must be created, with more to be defined as required:

- configuration access library

- parameter access library
- image access library

11.Template Module

A template module will be created by CFHT staff and available to all contributors.

12. External Dependencies

External dependencies are software tools and libraries developed outside the OPERA project that are required for operation. These tools and libraries may or may not be available in source form, but sources are not required. use of these tools and libraries may in no way restrict OPERA licensing. Any libraries which are judged to have unacceptable licensing will not be used. External dependencies should be kept to a minimum. That said, tools and software libraries such as “fitsverify” or “cfitsio” for example, will be used by OPERA. Other tools will be identified as needed.

13. Realtime Observatory Support

OPERA Core Reduction will handle file-by-file single image at a time reduction for use by observatories to calculate SNR values and spectra for feedback during observation. No other realtime support is planned.

14. Exclusions

While OPERA Core Reduction pipeline may produce equivalent products to Libre-Esprit, it will not use any Libre-Esprit software, as Libre-Esprit is not open source. OPERA is a software-only reduction pipeline and will have no interface to an actual detector or instrument. OPERA will have no impact on

hardware or detector software except that it requires that the instrument, detector, mode and speed be available in header keywords. There will be no graphical interface either for viewing products or control of the pipeline. CFHT quicklook-like capability is excluded from the scope of the Core Reduction pipeline. Data visualization tools are excluded from the OPERA Core Reduction pipeline.

15. Testing

Provision will be made so that OPERA software may be tested after integrations by an independent “test” user. A fixed test data set will be available to contributors. The results will be compared with Upena and previous releases of OPERA. CFHT will provide hardware servers for testing and run the test cases as part of the integration process.

16. Installation and Releases

OPERA software will be under source code control using CVS on Sourceforge and a CFHT-hosted computer (opera.cfht.hawaii.edu). CFHT personnel will set up Sourceforge and the CFHT opera computer. Builds will be tagged as releases. An installer will be constructed by CFHT to ease the addition of new team members.

17. Communication

CFHT staff will create an email alias at CFHT and also set up and email list and contributor list on Sourceforge.

18. Documentation

OPERA documentation should be in a format readable on multiple platforms. PDF is the suggested format. The harness, the software libraries and each module will be provided by the contributor. CFHT will also provide a test plan.

19. OPERA Deliverables

The instrumental signature removal includes bias subtraction, bad-pixel masking, flat-fielding, order tracking and fitting, pseudo-slit fitting, and wavelength calibration. At minimum OPERA will provide the following software modules to remove the instrumental signature (what is called "detrending" at CFHT) and, further reduction steps so as to provide similar products provided by the current Upena/Libre-ESpRIT pipeline:

- bias subtraction
- bad pixel masking
- cosmic ray rejection
- geometric calibrations: finding and tracking spectral orders, locating the "slit" and characterizing its shape
- flat-fielding
- extraction of (intensity) spectra, for all 3 Observing Modes (Star Only, Star+Sky, Polarization)
- use of a flat field response (solar spectrum) (optional)
- wavelength calibration based on comparison exposures
- correcting wavelengths based on telluric lines (optional)

- stitching orders together
- normalize the continuum (optional)
- calculation of polarized spectra for the Polarization mode with continuum polarization subtracted
- calculation of null polarization spectra
- sky subtraction for the Star+Sky mode
- calculation of error bars
- provide spectral resolution and S/N information for each order

CFHT will also provide the execution harness that controls execution of the modules, the parameter access library, the data access library and the image library.

CFHT will also provide test calibration in object images to aid in testing the core reduction pipeline.

20.OPERA Analysis and Post Reduction Steps

OPERA Analysis and Post Reduction Reduction steps are open ended. These optional steps will not will not run as part of standard reduction at CFHT and will not create products that will be released by CFHT. CFHT will however develop a *post reduction* distribution step as part of the CFHT release process. The harness will be developed in such a way as to make adding of these steps reasonably simple.

21. Personnel

CFHT will host and manage the OPERA project and ensure its' timely completion. CFHT will provide a resident astronomer to be the project scientist and also provide an additional collaborator. A CFHT Software specialist will be the project manager and Sourceforge gatekeeper. Other collaborators will be drawn from the scientific community on a volunteer basis.

22. Time Frame

The goal is to have the *OPERA Core Reduction pipeline* ready by the end of 2013 to have a useful lifetime for espadons. A complete schedule will be drawn up after the scope is accepted by the team.