Astronomical Data Analysis Software and Systems X
ASP Conference Series, Vol. 238, 2001
F. R. Harnden Jr., F. A. Primini, and H. E. Payne, eds.

The Basic Calibrated Data Processing Pipeline for SIRTF IRS

Fan Fang, Bob Narron, Clare Waterson, Jing Li, Mehrdad M. Moshir

SIRTF Science Center, Caltech

Abstract. The design and implementation of the data processing pipelines for the Infrared Spectrograph (IRS) onboard Space Infrared Telescope Facility (SIRTF) are presented. This includes pipeline for generating Basic Calibrated Data (BCD) in which instrument artifacts are removed, and calibration pipelines generating calibration data that allows reduction of the science data to the BCD level. Further reductions of BCD to generate Post-BCD products is also briefly discussed.

1. Introduction

The Infrared Spectrograph (IRS) will be one of the three instruments onborad NASA's Space Infrared Telescope Facility (SIRTF). Four instrument modules of IRS are designed and built to observe the mid-infrared ($5\,\mu m$ to $40\,\mu m$) spectra of astronomical sources in four overlapping wavelength channels with low- and medium-resolution dispersion optics and As:Si and As:Sb BIB detectors. The IRS Basic Calibrated Data (BCD) pipelines are designed to remove instrument artifacts introduced by a combination of optics and detector effects. The end-products are two-dimensional images containing spectra. Post-BCD processing pipelines will enable further reduction of the BCD frames to extract the one-dimensional spectra of observed sources.

2. Instrument Signatures

The spectra of astronomical sources are taken by the two-dimensional BIB arrays operated at a temperature of $\sim$5 K. There are four readout channels, and the analog-to-digital convertor is saturated at a level below the pixel full-well. The nominal data-taking mode for observing spectra is the so-called sample-up-the-ramp, in which pixels are read non-destructively during one Data Collection Event (DCE), and all readings are downlinked to the ground. So the pipeline typically deals with a data cube with multiple sampled layers in one DCE. A two-dimensional IRS spectral image has the following instrument artifacts:

1. dark current that is always present at the operating temperature, independent of exposure to outside the detector.
2. nonlinearity when a detector pixel contains more than a certain number of electrons.
3. pixel response variations across the array.
4. readout-channel dependent gain variations.

5. detector transient effects causing "jail-bar" patterns along the slow-read direction.
6. a "droop" effect in which the readout value of one pixel is affected by the presence of electrons in all other pixel wells in the array.
7. a short-timescale ($< 32\,\mathrm{sec}$) nonlinearity behaving differently from pixel to pixel.
8. radiation hits in space environment.
9. amplifier drift during consecutive DCEs.
10. a muxbleed effect in which a bright pixel trails in the fast-read direction every several pixels.
11. a blaze-function introduced by dispersion optics.
12. fringing caused by multiple reflections from instrument and optical interfaces.

Since the IRS has no shutter it will direct its slit to blank sky areas to take reference dark frames for calibration of dark current. The non-linearity effect is not expected to be significant since the A/D converter saturates at a level below full pixel well, but will be corrected. Although the detector has pixel-dependent ramp nonlinearity at short time-scale, the same behavior is persistent in different integration ramps with the same sample duration, so this can be corrected by layer-by-layer subtraction of a reference data cube such as the reference dark cube.

Radhits can be identified and removed by examining the discontinuities in the charge ramp. A segmented fit of the ramp is performed for each pixel and the probability and strength of the radhits are estimated using a Bayesian approach. The "droop" effect can be caused by both illumination and radhits so it should be accounted for before radhits are removed. Saturation at the A/D converter needs to be corrected since electrons are still accumulating in pixel wells and contribute to the "droop" level. Any remaining "droop", such as that caused by radhits in saturated pixels, can be removed by examining and subtracting the remaining median levels in unilluminated regions. Such unilluminated regions, where spectra orders are well-separated and order cross-talk effects are small, exist in all IRS arrays. Any channel-dependent effects can be similarly removed by examining and correcting remaining cross-channel median levels.

Flatfielding corrects for both optical dispersion function and pixel response variation. To estimate flatfield, a number of calibration sources with known continuum and spectral lines will be observed. The spectral lines in different sources will be masked, and a slit profile will be incorporated into the continuum spectrum which is removed from data.

3. The IRS Processing Pipelines

Figure 1 shows the current design of the BCD science and two calibration pipeline threads. They are shown as flowcharts illustrating the data reduction sequence and the software components in boxes that perform specific tasks. In the reference dark-current calibration, the amplifier drift is removed for consec-

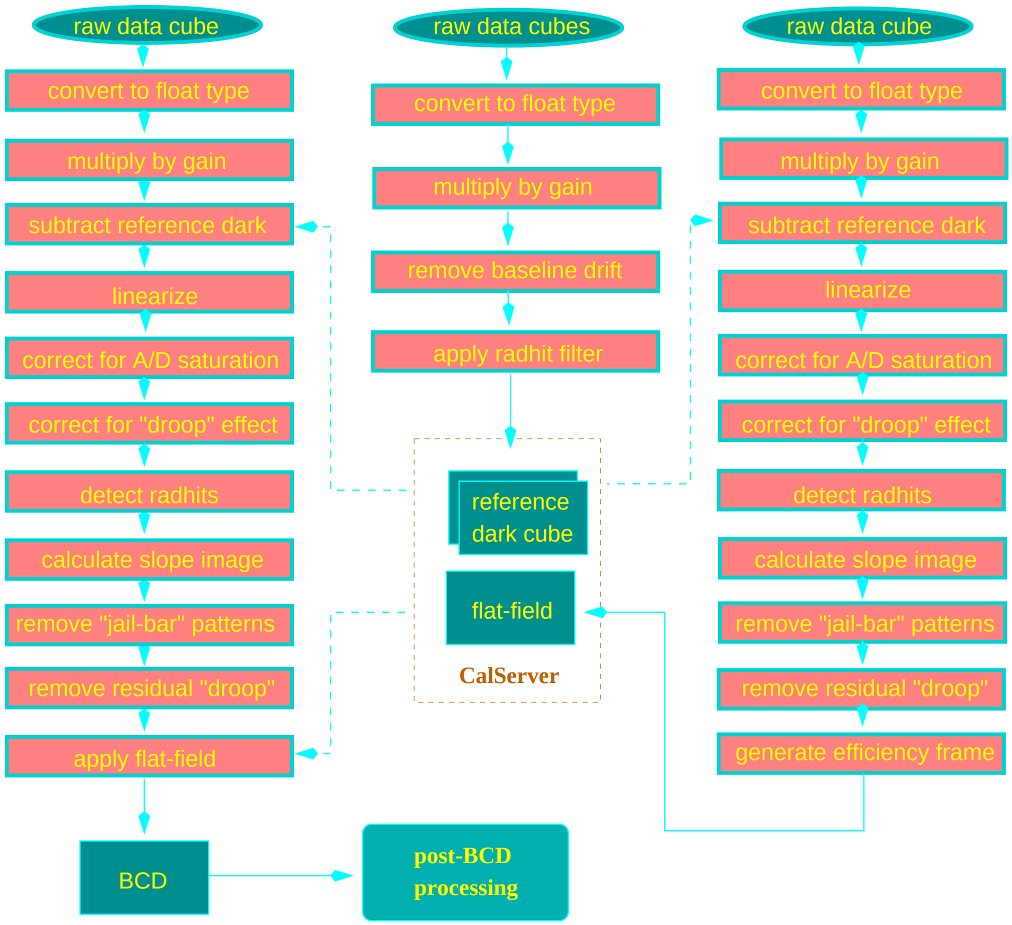

Figure 1. The current IRS BCD science data reduction (*left*), dark-current (*middle*) and flatfield (*right*) calibration pipelines shown as flow charts. The muxbleed effect correction and fringing removal will be included in these pipelines in their subsequent deliveries.

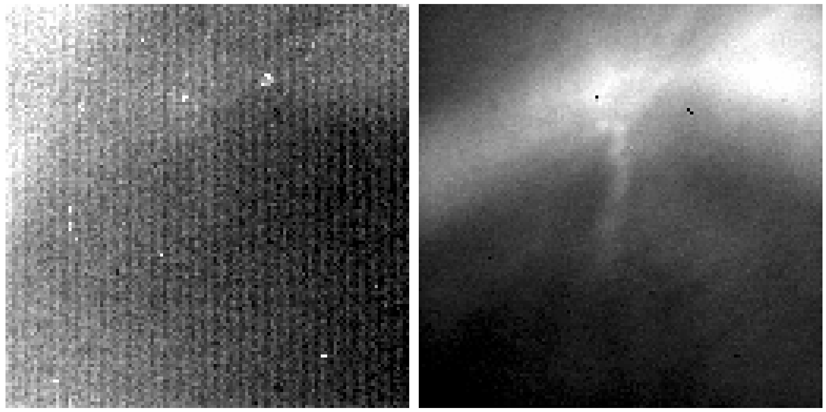

Figure 2. Reduction of the IRS BCD science pipeline using stimflash data. The image at left shows the highest sample in a ramp in the data cube as the pipeline input; the image at right shows the reduced result. So far we do not have ground spectra data in this data-taking mode and flatfield calibration is not applied to this reduction.

utive dark exposures. This is for correctly identifing small radhits during the subsequent median-filtering of the same data layers of many such exposures. The flatfield calibration follows nearly the same reduction steps as in the science pipeline, since flatfielding is performed at the end of the science pipeline. A result from the science pipeline reduction using stimulator data is shown in Figure 2.

Further reduction of the BCD is needed to generate spectra. The purpose is to make it straightforward to extract one-dimensional spectra from the two-dimensional BCD. This basically involves "straightening" of the spectra in both two-dimensional pixel space and one-dimensional wavelength space. We have implemented post-BCD pipelines that take into account the curvature of spectra and wavelength resolution elements to perform the "straightening". The pipeline uses a calibration file containing elements optimally sampled in wavelength space and their locations in pixel space in order to estimate the average profile of spectra orders and perform spectra extraction based on the profile.

The components in a pipeline are all stand-alone modules. Operationally the calling of a software module is communicated via wrapper scripts of the modules. A wrapper script can have extra capabilities such as communicating with calibration servers, checking input files, directing output files, setting database flags, etc., in addition to executing the corresponding module.