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An update on the development of ASPIRED

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Abstract. We are reporting the updates in version 0.2.0 of the Automated SpectroPhotometric REDuction (ASPIRED) pipeline, designed for common use on different instruments. The default settings support many typical long-slit spectrometer configurations, whilst it also offers a flexible set of functions for users to refine and tailor-make their automated pipelines to an instrument's individual characteristics. Such automation provides near real-time data reduction to allow adaptive observing strategies, which is particularly important in the Time Domain Astronomy. Over the course of last year, significant improvement was made in the internal data handling as well as data I/O, accuracy and repeatability in the wavelength calibration.

1. Introduction

ASPIRED - Automated SpectroPhotometric REDuction (Lam et al. 2019, hereinafter LSS19; Lam 2020), is a spectral data reduction software, written in Python 3, that is designed for common use on different instruments. Over the course of last year, it has been tested on several active instruments: SPRAT on the Liverpool Telescope (LT, Steele et al. 2004), ISIS on the William Herschel Telescope[1] (Lam et al. 2020), GMOS long slit (LS) mode on the Gemini Telescopes North (GTN)[2], and OSIRIS LS mode on the Gran Telescopio Canarias (GTC)[3]. Apart from LT/SPRAT, the test efforts are **not** in collaboration with the respective observatories.

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[1]`https://github.com/cylammarco/ASPIRED-example`

[2]`https://github.com/cylammarco/bhtomspec`

[3]`https://github.com/P-R-McWhirter/pyOsiris`

2.   What's new?

In the latest release, we have abstracted the spectral handling into a `_spectrum1D` class to handle all the data I/O of the extracted spectra. Wavelength and flux calibrations are operating on these objects, each level of calibration is stored and can be recalled for diagnostics. As laid down in the design requirements (LSS19), the spectral data reduction is modularised into 3 components at the highest level. We have a set of API that maps to every function available with the wavelength calibration software, RASCAL (Veitch-Michaelis & Lam 2019, 2020). They are both available through PyPI (i.e. `pip install aspired rascal`). Documentations are frequently updated on Readthedocs[4]. Files can be exported as FITS or CSV. More effort is still required to allow manual input or changes of FITS header keywords or comments. Automated testing is moved from Travis CI to GitHub Actions to simplify the process – unit tests and build tests are performed with Python 3.6, 3.7 and 3.8 on the latest versions of Windows, Ubuntu and MacOS (see more at `https://github.com/features/actions`).

3.   Application and Comparison with the current SPRAT pipeline

The red mode of LT/SPRAT with a Xe arc is our primary testing system and the data have most of the features and capabilities expected of an observatory's common-user, long-slit spectrograph. We are currently commissioning the new automated pipeline for it. This will be further extended to deploy a common pipeline for both LT/SPRAT and the MOOKODI spectrograph on the Lesedi Telescope in 2021. A separate prototype pipeline was implemented using YAML file as configuration file to fully control data reduction for refining LT/SPRAT and extracting GTN/GMOS LS spectra.

As one element of testing of the new software we compare its results to those from known and established software packages. Comparisons are based on a complete sample of all data taken with the LT/SPRAT (Piascik et al. 2014) spectrometer over two months (Jan - Feb 2020). See some examples in Figure 1 & 2. The sample includes 493 spectra with both point sources and extended targets in all observing conditions, from excellent to thick cloud or bright twilight, i.e., this tests all qualities of data a user is likely to encounter, good and bad. We compare performance of the new AS-PIRED pipeline to the existing SPRAT pipeline ('L2 pipeline') that was custom developed alongside the instrument and optimised to both the hardware and LT operational model. The full sample was passed through both pipelines. All raw data and output spectra were qualitatively assessed and rated as to whether the extracted spectrum was a reasonable representation of the data:

- Both ASPIRED and L2 produce believable result 401 (81%)

- Unusable data: cloud/observer error/technical faults 38 (8%)

- ASPIRED unable to extract a spectrum, but L2 pipeline did 52 (11%)

- L2 pipeline unable to extract a spectrum, but ASPIRED did 1 (0%)

- Neither pipeline extracted a spectrum 1 (0%)

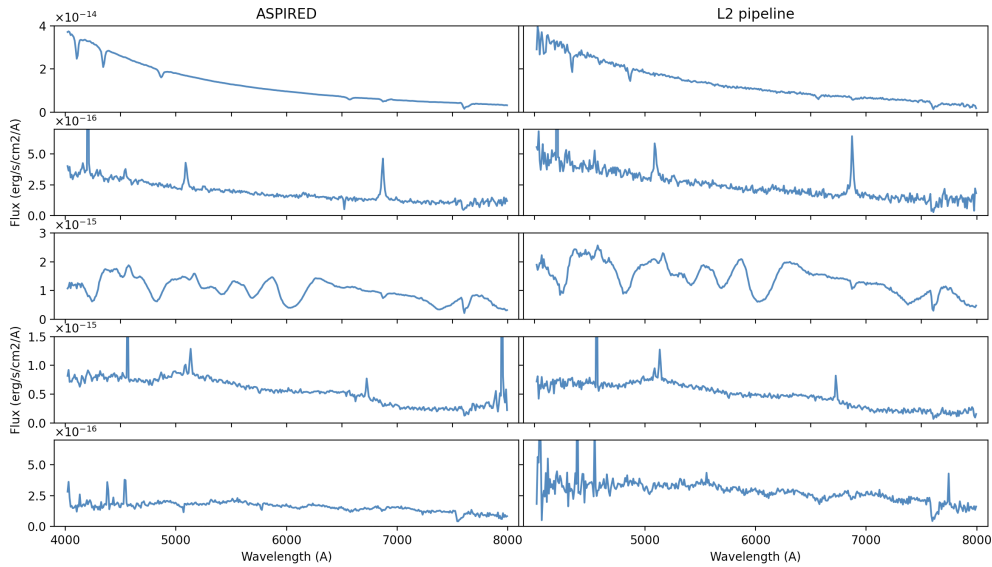
[4]`https://aspired.readthedocs.io/`

Figure 1.   Some examples comparing results from the two pipelines are shown in accompanying figure. In virtually all cases the ASPIRED extraction is obviously higher in the signal-to-noise.

The vast majority of the ASPIRED 'failures' are extremely low signal-to-noise spectra where the bespoke L2 pipeline was able to use forced extraction through its a priori knowledge of the instrument's configuration. In contrast ASPIRED was being run using generic defaults that require it to detect the source in the slit. It successfully extracted 91% of the frames that the bespoke pipeline did and achieved higher signal-to-noise (Figure 1). We do not optimise ASPIRED defaults to the one SPRAT instrument. A user would be able to provide such instrument-specific knowledge into any pipeline.

4.   Wavelength Calibration - RASCAL

RASCAL – RANSAC-Assisted Spectral Calibration is designed to solve for the pixel-wavelength function requiring only an atlas of calibration lines (wavelength), a list of peaks (peaks), and some information about the system (wavelength range). The development in the past year has (1) improved the robustness; (2) added more instrumental systems; (3) a cleaned line list that is more suited for low/medium resolution spectrograph; and (4) allowed users to supply custom lines. These improvements allow rapid convergence of the solution when fitted with a fine tuned line list provided by the observatory. A number of examples are available at Readthedocs page[5], including: (1) Liverpool Telescope - SPRAT (red mode), (2) William Herschel Telescope - ISIS (R300R), (3) New Technology Telescope - EFOSC (Gr#11), (4) Gemini North - GMOS-LS (R400+G5305), (5) Gran Telescopio Canarias OSIRIS-LS (R1000B), (6) Issac Newton Telescope - IDS (R1200U), and (7) Keck II Telescope - DEIMOS (830G).

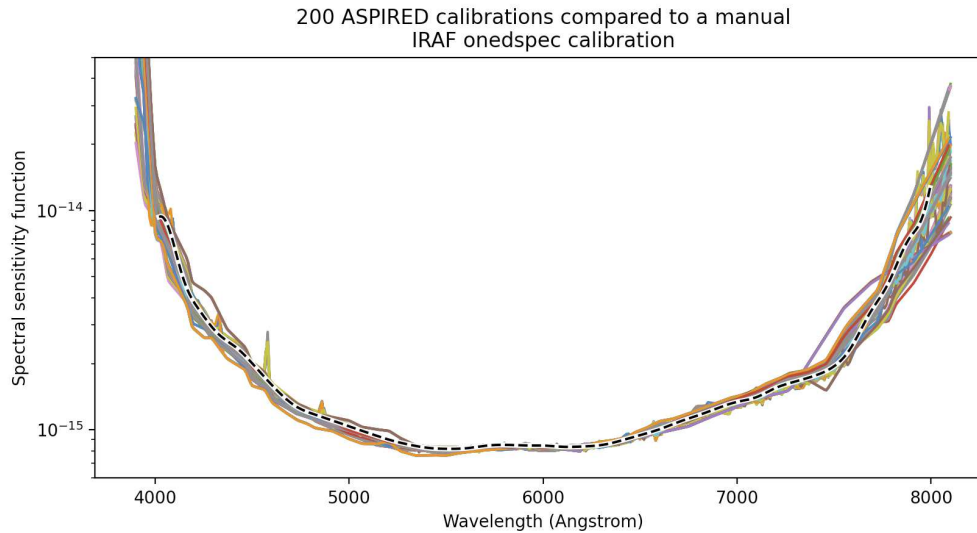[5]https://rascal.readthedocs.io/en/latest/

Figure 2.   In an alternative check we compare the automated spectral sensitivity curves generated by ASPIRED on default settings (coloured lines) to a calibration that was manually and interactively derived in IRAF by an experienced observer combining observations of multiple different spectrophotometric standards (dashed line). They are all normalised to each other to compare just the shapes.

5.   Development and Release Timeline

ASPIRED is currently at version v0.2.0, we expect updates and bug fixes in month-scale. We will continue to expand and improve the API to provide more functions to delivery higher quality and flexibility. The concurrent development of RASCAL will continue to support ASPIRED and we are looking to expand to handle calibrations for different variants of multi-object spectrograph.

References

Lam, M. C. 2020, cylammarco/ASPIRED: Initial Development Release v0.2.0. URL `https://doi.org/10.5281/zenodo.4306065`

Lam, M. C., Hambly, N. C., Lodieu, N., Blouin, S., Harvey, E. J., Smith, R. J., Gálvez-Ortiz, M. C., & Zhang, Z. H. 2020, MNRAS, 493, 6001. `2002.11014`

Lam, M. C., Smith, R. J., & Steele, I. A. 2019, arXiv e-prints, arXiv:1912.05885. `1912.05885`

Piascik, A. S., Steele, I. A., Bates, S. D., Mottram, C. J., Smith, R. J., Barnsley, R. M., & Bolton, B. 2014, in Ground-based and Airborne Instrumentation for Astronomy V, edited by S. K. Ramsay, I. S. McLean, & H. Takami, vol. 9147 of SPIE Conference Series, 91478H

Steele, I. A., et al. 2004, in Ground-based Telescopes, edited by J. Oschmann, Jacobus M., vol. 5489 of SPIE Conference Series, 679

Veitch-Michaelis, J., & Lam, M. 2020, Rascal. URL `https://doi.org/10.5281/zenodo.4117517`

Veitch-Michaelis, J., & Lam, M. C. 2019, arXiv e-prints, arXiv:1912.05883. `1912.05883`