Data-Reduction Tools for Fabry-Perot observations at the SOAR Telescope.

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ABSTRACT

The SOAR Telescope now counts with a new observation mode called SAM-FP. It consists of a Fabry-Perot (FP) interferometer installed within the SOAR Adaptive Module (SAM) and it allows us to perform 3D spectroscopy over a field of 3 x 3 arcmin and with a resolving power of 11200 near Hα. We present here the status of our efforts in developing these tools to reduce FP data that is currently being done using Python and the standard libraries for astronomy. The available tools can be used to perform the basic image reductions, build data-cubes, extract phase-maps, fit them and apply them to the science cubes. Finally, they perform wavelength calibrations and extract the main 2D maps from these cubes. We will focus on performance of the existing tools applied to simulated and real data.

1. Introduction

SAM-FP[1] is a new observation mode available at the 4-meter SOAR Telescope, on Cerro Pachón, near the Elqui Valley, Chile. It consists of a Fabry-Perot (FP) interferometer installed in the collimated space of the SOAR Adaptive Module (SAM). SAM uses Ground Layer Adaptive Optics (GLAO) to enhance image quality in the visible part of the spectrum[2, 3].

SAM has a dedicated imaging system called SAM Imager (SAMI) that covers a field of 3 x 3 arcmin with a e2v CCD with 4096 x 4112 pixels and 45.5 mas per pixel. SAM-FP delivers data-cubes via scanning mode. Table 1 displays information about the FP we have available and the main characteristics of the data.

	Nominal Gap Size	Free Spectral Range (FSR)	Spectral Resolution
High Resolution FP	200 μm	10.8 Å (492 km.s^{-1} @ Hα)	≈ 11 200
Low Resolution FP	44 μm	48.98 Å (2237 km.s^{-1} @ Hα)	≈ 4 200

Table 1 – Fabry-Perot Nominal and Measured Parameters

The information for each wavelength in a data cube obtained with Fabry-Perot follows parabolic surfaces inside the cube (Figure 1). Proper manipulation is needed to recover the (x, y, λ) information. SAM-FP tools is a set of scripts focused on these manipulations. The standard processing is described below.

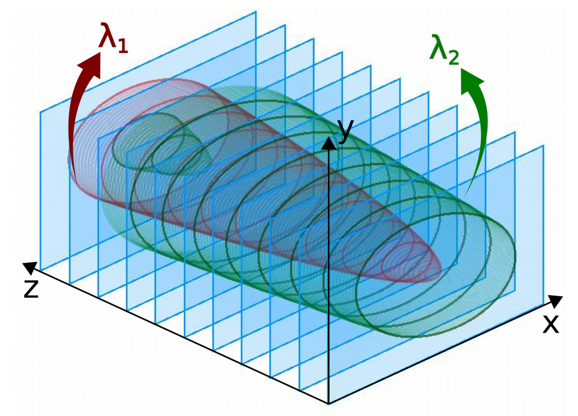

Figure 1 – Artistic concept of the wavelength distribution within a data-cube obtained with FP observation.

2. SAM-FP Tools

Figure 2 displays the standard data reduction flux for SAM-FP data using the SAM-FP Tools[a] written in Python using AstroPy[4] and standard libraries. The **`xjoin`** script is designed to easily perform standard data reduction that is usually done using IRAF[5]. It merges the extensions of the FITS files, does bias subtraction, applies flat correction and clean cosmic-rays using LaCosmic[6].

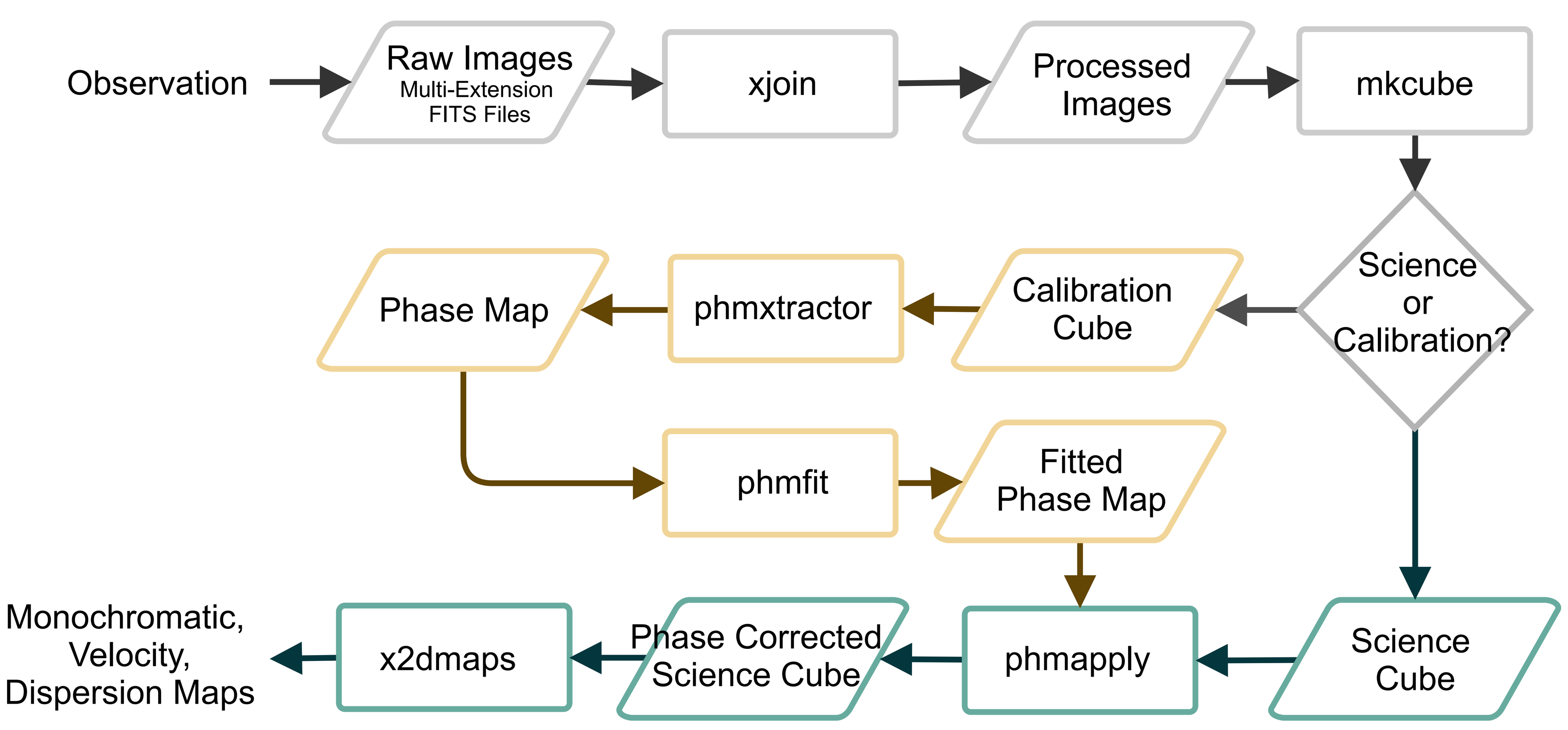

Figure 2 – SAM-FP Tools standard data reduction flux.

The phase corrections process is divided into three steps and is processed using three scripts:

`phmxtractor` – Finds (FSR), the center of the rings and extracts the relative displacement between the spectral inside a FITS image, the phase-map.

`phmfit` – Unwraps the phase-map and fits the phase-map to a parabola.

`phmapply` – Applies the phase-map in the science cube and find the wavelength calibration using the science target's emission wavelength, systematic velocity and the FP nominal gap size.

[a] https://b1quint.github.io/samfp-tools/
[b] https://b1quint.github.io/illusion/
[c] https://github.com/rcbrgs/tuna

The phase-correction process was tested by plotting the spectral along the central column of the data-cube before (Fig 3a) and after phase-correction (Fig 3b). The central reference spectrum is also compared to the averaged spectra in the phase-corrected cube, (Figure 3). These plots were produced using simulated data-cubes using Illusion[b, 9].

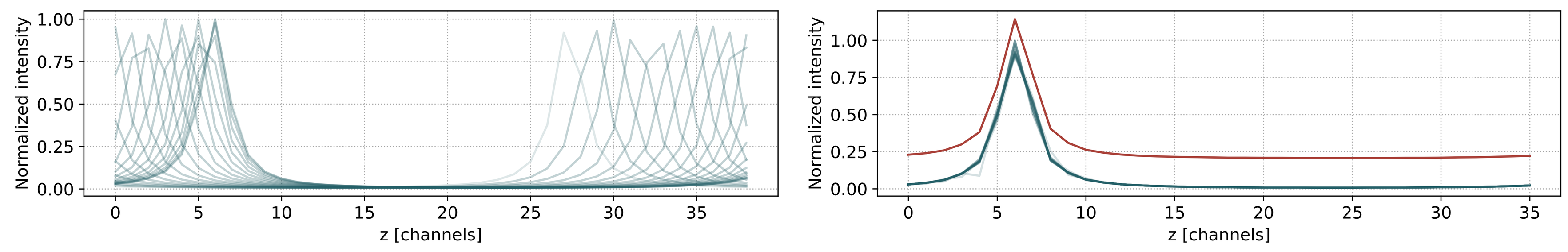

Figure 3a – Before phase-correction. Figure 3b – After phase-correction.

Figure 3 – Phase-correction tests using simulated data. The green lines represent the spectra over the central column and the orange line (Figure b) shows the averaged spectra in the cube. An offset was added to the averaged curve to make the visualization easier.

Figure 4 shows the 2D maps extracted from 30 Dor. This data was originally presented by Mendes de Oliveira et al. (2017)[1], where different tools where used to reduce the data. We find consistent values in the velocity map (Fig. 4b) but higher dispersions (Fig. 4c) due to instrumental and thermal effects that are not corrected yet.

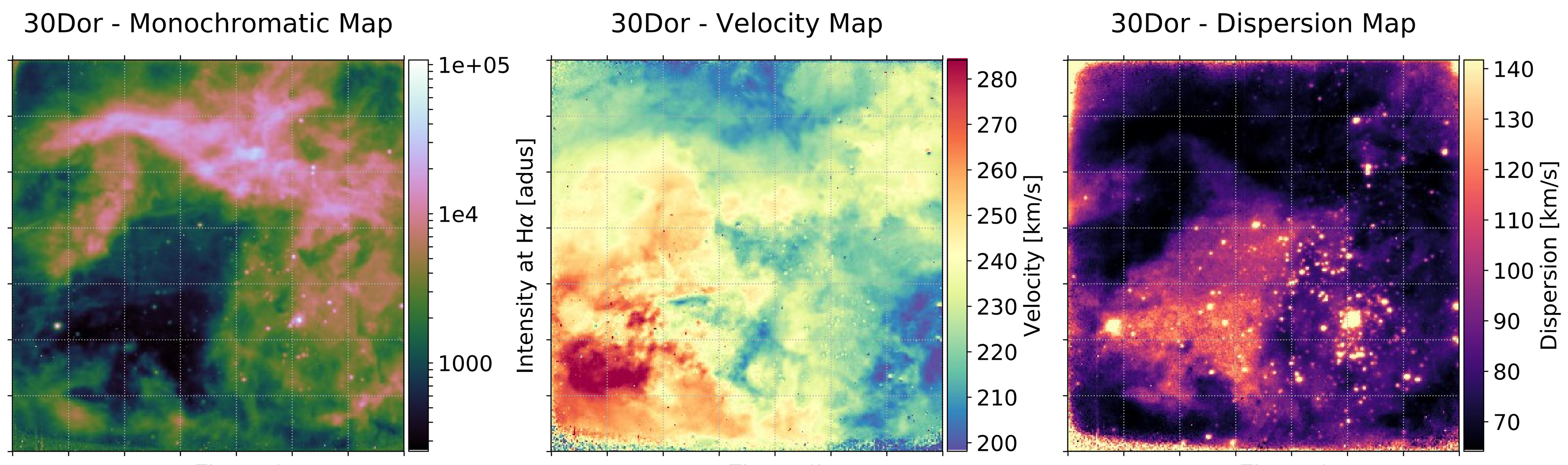

Figure 4a Figure 4b Figure 4c

Figure 4 – 30 Dor observed on March 17th, 2015 (Mendes de Oliveira et. al., 2017).

4. Conclusions and future work

SAM-FP tools is an ongoing work. The most critical steps were covered but details must still be attacked. Here is the list of known issues that are still pending:

- Integrate data-reduction tools into single line;
- Correct SAMI's Field Distortion;
- Incorporate astrometric solution in the SAM-FP Tools;
- Extract 2D maps where for spectra with SNR above a given threshold;
- Implement advanced techniques to increase SNR[8];
- Correct instrumental signatures and sky emission lines[9];
- More robust algorithms to deal with “messy” data;
- Implement integrated tests and check consistency;
- Merge with TUNA[c] – another set of tools for FP data developed by the Laboratoire d'Astrophisique de Marseille that we had some participation.

Acknowledgments

This work is done using Astropy, a community-developed core Python package for Astronomy. It is also part of a work developed at the Southern Astrophysical Research (SOAR) telescope, which is a joint project of the Ministério da Ciência, Tecnologia, Inovação e Comunicações (MCTIC) do Brasil, the U.S. National Optical Astronomy Observatory (NOAO), the University of North Carolina at Chapel Hill (UNC), and Michigan State University (MSU). IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation. We acknowledge the support from CPNQ (process 205459/2014-5) by funding the Post-Doc Fellowship of Bruno Quint. We warmly acknowledge funding from FAPESP (processes number 2014/07684-5 and 2006/56213-9).

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