Opera team

OPERA Final report

Opera reduction software can extract ESPaDOnS's spectrum using all observing modes (Polar, Star+Sky and StarOnly) and readout modes (Slow, Normal, Fast). Flux is normalized and unNormalized, with or without wavelength correction for spectrograph drift (using telluric absorption lines).

- Overall, Opera gain and noise values are similar to Libre-Esprit. The Opera heliocentric velocity correction is within 20 m/s of Libre-Esprit.
- The wavelength calibration precision and RV dispersion can be compared as such:

Unit : m/s	Median (telluric corr) between Opera and Libre-Esprit	Rms (telluric corr) between Opera and Libre-Esprit	Wavelength precision	Night RV dispersion
Opera	30	100	100	50
Libre-Esprit			300	20

- Figure 1 shows comparison between OPERA (red) and Libre-Esprit (black) telluric correction for a whole night.

1. Polarimetric mode

- For all readout speeds, there is a loss of power resolution compared to Libre-Esprit. The median of the amplitude of the loss is 8,000 or 12%.
- Opera SNR on the StokeI (intensity) is within 10% of the Libre-Esprit value, with better performances in the red regime. The SNR per StokesV is not computed by Opera.
- Opera as Libre-Esprit is removing the continuum polarization.
- LSD analysis performed on Opera reduced spectra shows that loss of power resolution combined with non-accurate telluric correction (higher dispersion) lead to a mean Stoke I profile width broader compared to Libre-Esprit LSD analysis. The amplitude of the broadening depends on the spectral type. For F-K dwarfs, the broadening is less than 1% (for high SNR spectra). For M-type dwarf, the increase is between 5-8%.
- LSD analysis was also performed on Stoke V, showing once again an artificial broadening compared to Libre-Esprit. The amplitude is less than 2% (for F-K-M dwarf taken under high SNR spectra).
- Radial velocity analysis was performed to quantify the impact of this artificial broadening. A monitoring of HD189733 (September 2013) was used leading to a radial velocity dispersion of 55 m/s with Opera compared to 24 m/s with Libre-Esprit (after removing the orbit). See Figure 2.
- Opera Polar signature for HD189733 is noisier (by a factor 1.5) compared to Libre-Esprit, and the amplitude is 30% higher compared to Libre-Esprit.
- The null vectors (N1 and N2) are computed by Opera. For high SNR spectra, those null vectors are similar to Libre-Esprit.

- For observation taken under medium-low SNR (100-150), M dwarfs are showing a broadening of 5% on the mean Stoke I profile. As an example on Figure 3, the Stoke V spectrum shows spurious signature.

2. Spectroscopic modes (Star+Sky and Star Only)

- For both spectroscopic modes, there is a loss of power resolution compared to Libre-Esprit. For Star+Sky and StarOnly, the median of the amplitude of the loss is 10,000 or 15% and 12,000 or 15%, respectively.
- On the version of Opera tested for this report, SNR for Star+Sky mode is always lower (between 20-40%) compared to Libre-Esprit over the whole spectrum. This issue appears to be the result of a recent change to Opera, and a potential fix has been implemented, but remains to be thoroughly tested.
- Opera is performing Sky subtraction showing a difference of 20% with Libre-Esprit based on long exposure (~1800s).
- The Opera mean Stoke I profile width is still broader compared to Libre-Esprit LSD analysis (up to 10%).

3. Conclusion on performances and comparison to Libre-Esprit

- In summary, Opera reduced spectrum is similar to Libre-Esprit for A-G-M type stars at high SNR (> 300). The Opera Flux normalization is similar to Libre-Esprit for A-G type dwarfs.
- Opera reduced spectrum has major limitation compared to Libre-Esprit for the overall power resolution (loss 10-15%), telluric correction (higher dispersion) and flux normalization for M-type dwarfs. Those major limitations have a significant impact on the extracted SNR and mean line profile width.
- The Star+Sky reduced spectrum shows major limitations on SNR and sky subtraction. However, a potential fix has been implemented, but remains to be thoroughly tested.
- Opera polarized signal (StokesV) is 30% higher compared to Libre-Esprit, which imply a 30% higher magnetic field.
- For StokesI (intensity), Opera can be used safely on stars with most of their spectral contain bluer than 700nm and with SNR higher than 300.

4. Opera package

- Package available on SourceForge: https://sourceforge.net/projects/opera-pipeline/
- Installation guide and Dependency tutorial are part of the package available on SourceForge.
- Opera software was largely tested on Unix machine and doesn't work on Mac OS x 10.11.5.

5. Opera Documentation

- A technical paper explaining the algorithms used by Opera has created, which will be made available with Opera. The paper is currently being updated to reflect the current state of the pipeline.
- Scientific paper is in preparation
- Website : http://www.cfht.hawaii.edu/en/projects/opera/
- Wiki based at LNA: http://200.131.64.73/wiki/espectro/index.php/Main_Page

6. Opera for Graces

- Graces data can be reduced with Opera, by modifying the input parameters (makefiles).
- Graces reduced data will have the same limitations than ESPaDOnS's data, since all reduction modules are the same.
- CFHT is not providing support for the reduction of Graces using Opera.

7. Summary and proposed ending project

- Opera was designed as a software reduction, which has several limitations when trying to use it as the official observatory pipeline, when it should work on a daily basis for all spectral type and SNR level.
- Opera can be use by the community with careful look at the results and documentation has to be provided.

Figure 1: Left panel: Telluric correction estimated by Opera (red) and Libre-Esprit (black). Right panel: Difference between both software.

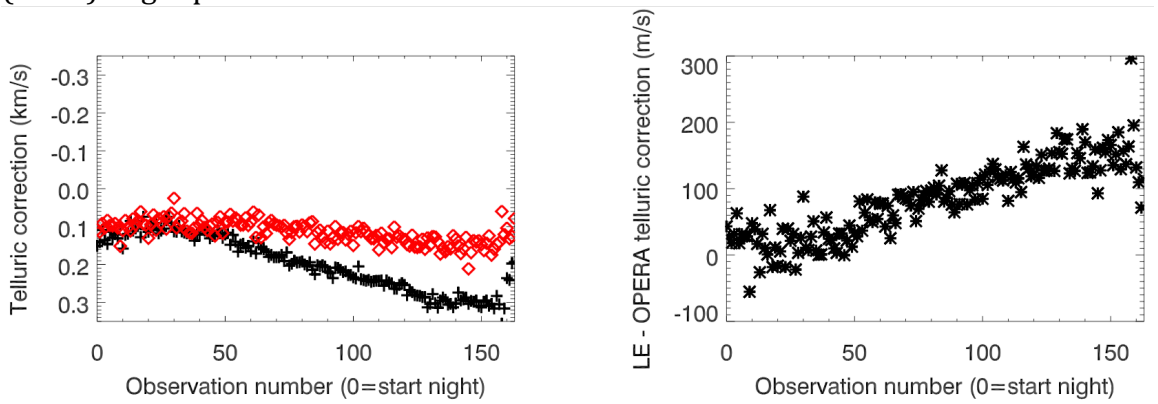

Figure 2 : HD189733 Radial velocity monitoring

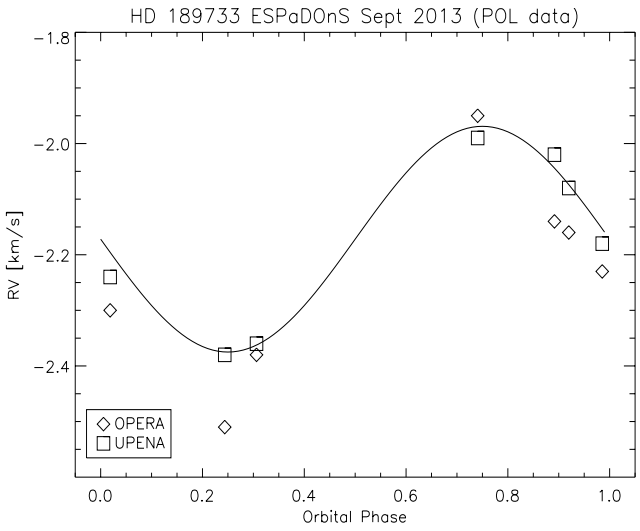

Figure 3: M dwarf low SNR (100 per exposure), Texp=700s. A spurious detection is seen on the polarized spectrum.