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## Telescopio Nazionale Galileo

### HARPS-N DRS User Manual

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Manual version 1.2  
TNG-MAN-HARPN-0006

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# 1 Introduction

## 1.1. Scope

This DRS Manual is intended to give all necessary information to potential users of the HARPS-N instrument, to help them to use the instrument and manages the observation at the TNG telescope.

This manual is focussed on the ESPRESSO DRS installed the 28th of October 2021, although refer to the previous version to facilitate the transition from the original DRS-32 to the ESPRESSO DRS, especially in the first period of overlap of the two DRS.

The following documents are closely related to these manuals and should be consulted as well:

- The HARPS-N Quick Start Guide (TNG-MAN-HARPN-0001)
- The HARPS-N User Manual (TNG-MAN-HARPN-0002)
- HARPS-N Operation Guide (TNG-MAN-HARPN-0003)
- HARPS-N Autoguide Manual (TNG-MAN-HARPN-0004)
- The New Short Term Scheduler User Manual (NSTS)
- The DRS User Manual (OG-MAN-HAN-13-0004)
- The standard calibration

These manuals are available through the TNG web page

<http://www.tng.iac.es/instruments/harps/>

## 1.2. Additional information

The latest information updates about the HARPS-N instrument can be found on the HARPS-N web pages

<http://www.tng.iac.es/instruments/harps/>

## 1.3. Contact information

Feedback on this User Manual from users is encouraged. Please email to [cosentino@tng.iac.es](mailto:cosentino@tng.iac.es)

## 1.4. Acknowledgments

The HARPS-N pipeline has been designed, implemented and developed by the Geneva Observatory.

Most of the contents of this manual is based on information from Xavier Dumusque, Nicolas Buchschacher and Francesco Alfonso Pepe. Thanks to Xavier Dumusque, Nicolas Buchschacher, Francesco Alfonso Pepe, Christophe Lovis and Danuta Sosnowska for the development of the HARPSN DRS.

## 1.5. Reference documents

- [RD01] HARPS-N User Manual
- [RD02] HARPS-N Operational Guide
- [RD03] HARPS-N Quick Start Guide
- [RD04] HARPS-N LCU Manual
- [RD05] New Short Term Scheduler User Manual (NSTS)
- [RD06] DRS User Manual
- [RD07] Ucam User manual
- [RD08] Templates Reference Guide
- [RD09] Thorium-Argon Atlas
- [RD10] Design of the LCU for HARPS-N
- [RD11] HARPS-N Autoguide Manual
- [RD12] The standard calibration

## 2 DRS Overview

The ESPRESSO DRS web UI has a few panes-sections displaying the usual raw file listing of the ongoing night/afternoon, processing log, quality check info and the plot relevant to each exposure type.

All these are within the same web page of the browser.

Controls are available for navigating between the previously processed frames and their processing logs, zooming on the figures and saving them in on the saving plots, etc.

The ESPRESSO DRS implements an extended variety of masks, compared with the original DRS, with color correction for M dwarf and an increased night-to-night and long-term precision and speed in RV calculation.

Extensive feedback from the users on the ESPRESSO DRS is encouraged in order to resolve all potential issues and improve the software, especially during the initial period of its operation.

The ESPRESSO DRS , with offline and online (trigger) modes, is installed and running. The data products created by the ESPRESSO DRS are different from those produced by the old one.

Starting now, the ESPRESSO DRS will be used during the afternoon calibrations and night-time observations to obtain the reduced data, in particular for real-time monitoring of the data quality and as aid to observing strategy assessment.

The DRS software reside in a virtual machine, accessible from the 'brunello' workstation by clicking in the HARPS-CONNECT-NEW-DRS icon located in the desktop (Figure 3).

Another option to open a terminal in the DRS machine is:

- 1) Open a terminal in a linux machine
- 2) Open a DRS terminals by executing:  
`ssh -X drs@161.72.92.17`

## 3 The Data Reduction Software

### 3.1. The HARPS-N Workstation environment

The workstation environment in the control room is shown in Figure 1 . The workstation WSOPER is under the control of the Telescope Operator (TO), the Brunello and WSASTRO workstations are under the control of the Visitor Astronomer (VA) and finally the Multimedia workstation is shared between the TO and the VA (in COVID-19 time the Multimedia workstation is under the control of the VA only).



Figure 1 - Control room workstations

The TO can connect to the brunello workstation by using the VNC viewer, to operate with the DRS.

### 3.2. The DRS-32 Startup procedure (original DRS)

The DRS-32 software reside in a linux machine (drs32.hn), accessible from the 'brunello' workstation by clicking in the HARPS-DRS icon located in the desktop (Figure 3).

Another option to open a terminal in the DRS machine is:

- 1) Open a terminal in a linux machine
- 2) Open a DRS terminals by executing:  
**ssh -X harpn@161.72.92.15**

Then, to start the DRS-32, the commands are:

- `./start_DRS.csh` (for night observations)
- `./start_DRS_SOLAR.csh` (for solar observations)

These commands open the DRS-32 interface and the DS9 viewer (Figure 2) and start the reduction of the current day data.



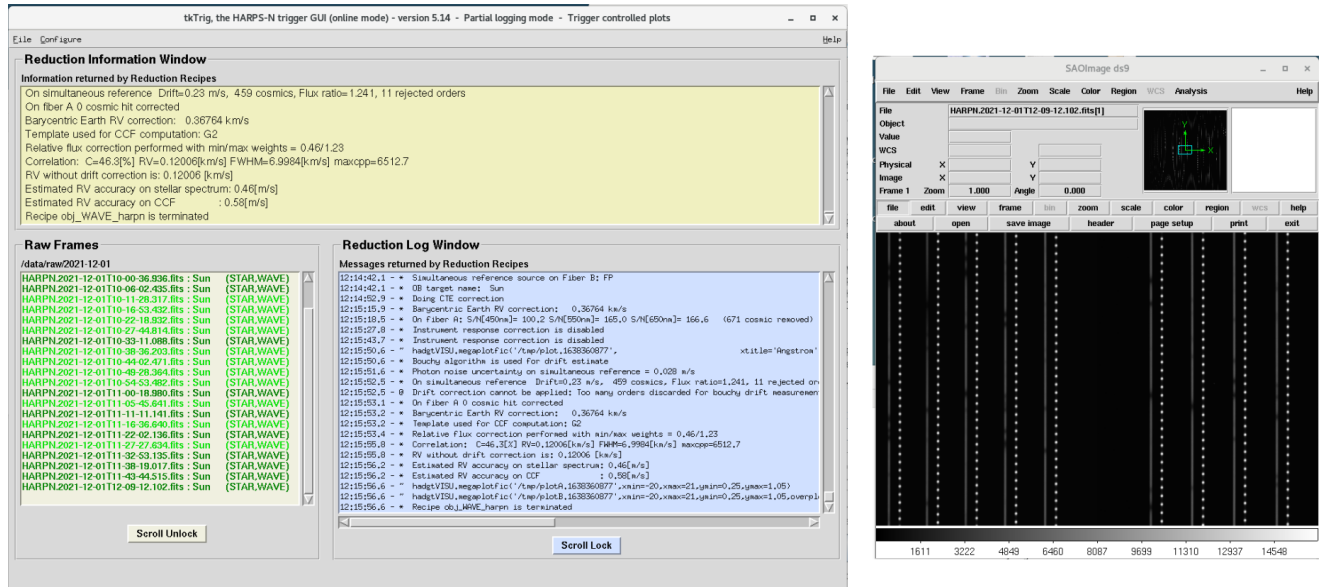


Figure 2 - DRS Interface (left) and DS9 viewer (right)

### 3.3. DRS Start-up/stop procedure (ESPRESSO DRS)

This paragraph describes the operations of how the ESPRESSO DRS has to be started for the reduction of the data at the telescope during the observations.

In the next paragraphs will be provided more details about the new DRS and the use of the trigger in online and offline mode and finally, in the paragraph 3.5 will be described the WEB Interface.

The DRS software reside in a virtual machine (161.72.92.17), accessible from the 'brunello' workstation by clicking in the HARPS-START-NEW-DRS icon located in the desktop (Figure 3).

This icon launches the online trigger and open the browser on the web page of the DRS GUI.

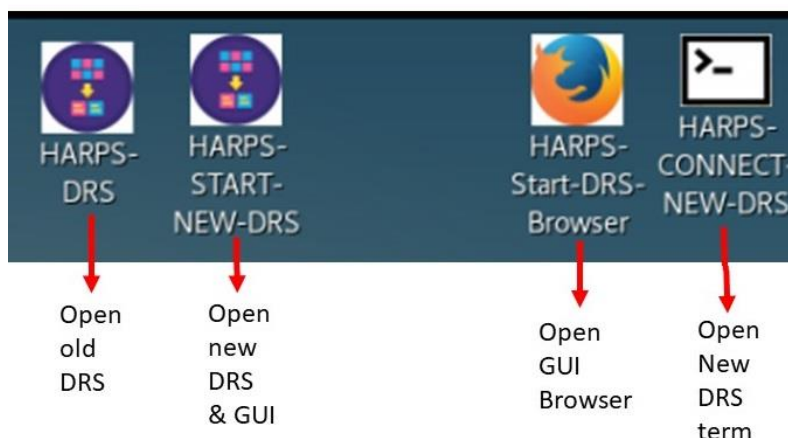


Figure 3 - Brunello workstation desktop

To stop the data reduction and close the WEB GUI press CTRL-C on the DRS terminal.

### 3.4. The DRS trigger (ESPRESSO DRS)

The ESPRESSO DRS software reside in a virtual machine, accessible from the 'brunello' workstation by clicking in the HARPS-CONNECT-NEW-DRS icon located in the desktop (Figure 3).

Another option to open a terminal in the DRS machine is:

- 1) Open a terminal in a linux machine
- 2) Open a DRS terminals by executing:  
`ssh -X drs@161.72.92.17`

The trigger is available in **online mode** or in **offline mode**. The difference is that the offline mode is used to reduce one chosen night without the GUI interface, while the online mode reduces the current night, starts the WEB server (to use the GUI interface) and wait for new frame.

**After that, to start the trigger online the commands are:**

1. `cd Trigger`
2. `python OnlineTrigger.py [options]`

The Online version also starts the **bokeh server** for the GUI to be able to connect from a browser on port specified in the config (default is 5006) (par. 3.5)

The available options are shown in Table 1.

**Example: `python OnlineTrigger.py -i HARPN`**

**Table 1 - Available online Options**

Options	Shortcut	Description	Default
--instrument	-i	Specify the instrument (ESPRESSO, HARPS, HARPN)	No default but mandatory
--night	-n	Specify the night to work on (YYYY-mm-dd). If not provided, default night is today	Today
--start-time	-st	Modify the reference start-time (9:00 by default) before which the online Trigger waits and compute the current date	09:00
--force-reprocess	-fr	Force to reprocess the already processed frames.	FALSE
--log-level	-l	Specify the log level (INFO, DEBUG)	INFO

To start the trigger offline **the commands are:**

1. `cd Trigger`
2. `python Trigger.py [options]`

The available options are shown in Table 2.

By default the offline version does not start any **bokeh server** but is used in command line only. The user can start a separate bokeh server with the following command:

3. `bokeh serve gui --allow-websocket-origin=[IP_ADDRESS:PORT] --arg [night]`

Table 2 - Available Offline Options

Options	Shortcut	Description	Default
--instrument	-i	Specify the instrument (ESPRESSO, HARPS, HARPN)	No default but mandatory
--file	-f	Give the path of a file containing the list of frames to be reduced (absolute path, 1 path per line)	No default but -f or -p is mandatory for the Trigger to process a set of frames
--path	-p	Same as -f, but directly provide the path of the frames to be reduced in args	No default but -f or -p is mandatory for the Trigger to process a set of frames
--type	-t	Specify the frame types to be reduced (BIAS, DARK, LED_FF, ORDERDEF, FLAT, WAVE_FP_FP, WAVE_TH_DRIFT_THAR, WAVE_TH_DRIFT_FP, CONTAM_THAR, CONTAM_FP, EFF_AB, FLUX, SCIENCE_DARK, SCIENCE_SKY, SCIENCE_THAR, SCIENCE_FP, SCIENCE_DARK_SUN, SCIENCE_THAR_SUN, SCIENCE_FP_SUN)	Empty which means all frames
--mode	-m	Not allowed in HARPSN	Empty which means all modes
--log-level	-l	Specify the log level (INFO, DEBUG)	INFO
--recipe-options -	-ro	Pass specific recipe options to the esorex command	Empty

### Examples

**Standard example:** `python Trigger.py -i HARPN -p "[path_to_raw_dir]/2021-10-12/*.fits"`

**With Custom options:** `python Trigger.py -i HARPN -p "[path_to_raw_dir]/2021-10-12/*.fits" -t "BIAS,ORDERDEF"`

**With a file containing the raw frame list:** `python Trigger.py -i HARPN -f [path_to_input_file.txt] -t "BIAS,ORDERDEF"`

In the last example, `input_file.txt` must contains 1 or several lines with a path on each line.

```
/data/raw/2021-10-12/HARPN.2021-10-12T*.fits
/data/raw/2021-10-13/*.fits
```

## 3.5. The ESPRESSO DRS web interface

The DRS WEB interface is opened automatically when the ESPRESSO DRS is started by click on the HARPS-START-NEW-DRS icon (Figure 3).

Alternative ways to open the DRS WEB GUI are:

From Brunello workstation: click on the **HARPS-START-DRS-Browser** icon.


From any browser the link is: <http://161.72.92.17:5006/gui>

**The WEB GUI can be divided into four quadrants (Figure 4):**

- RAW frames (red box)


- Log information about the current frame (green box)
- Information about the reduced product corresponding to the selected RAW frame (LOG, QC, SOF) (blue box)
- Information about the reduced product corresponding to the selected RAW frame selected RAW frame (CCF, SNR, S1D, RAW) (black box)

In the black quadrant (lower right quadrant) are available some tools to improve the visualization of the information (3.5.4).

 Pan tool (to move the visualized graph)

 Box Zoom

 Box Select (X-axis)

 Wheel Zoom

 Save

 Reset

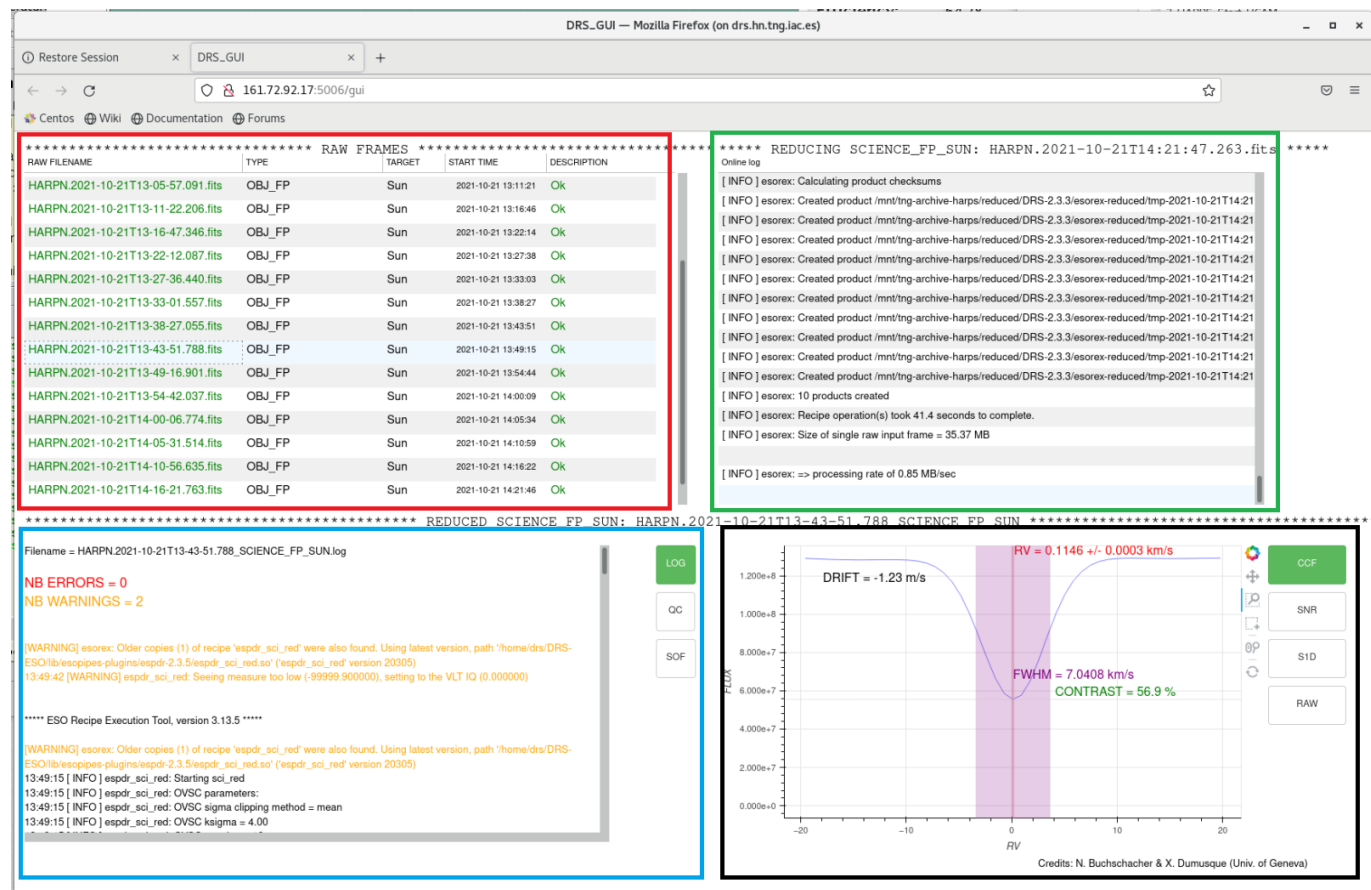


Figure 4 - The WEB GUI

### 3.5.1. Red panel: Raw Frame Box

In this quadrant are shown the RAW frames, as soon as the frames are acquired. The frames appear in black if they have not been reduced yet, in blue if they are reducing, green if they were reduced correctly and in red if some error is detected. In case of a failed reduction, an error message will be shown in the DESCRIPTION column.

### 3.5.2. Green pane: Log information about the current frame

While the raw file is reduced, in this frame is shown the log of the current reduction. The warning and errors are shown with different colours.

### 3.5.3. Blue panel: Information about the reduced product corresponding to the selected RAW frame

This panel will always show the information relative to the latest RAW frames reduced (except if when opening the GUI, some frames are already present in the RAW frame panel. However, if a new frame is reduced at this stage, the information from this latest frame reduced will appear). You can also show the information from other frames if you click with your mouse on a different frame in the RAW frame panel. Please note that as soon as a new frame is reduced, this panel will be update automatically with the latest frame information. The information shown in this frame depends on the button selected in the right part of the frame (LOG, QC, SOF).

#### 3.5.3.1. LOG

If the LOG button is selected, the log of the selected frame is shown in this quadrant of the GUI (Figure 5). The errors are shown in red and the warning in orange.



Figure 5 - Log information of the selected frame

### 3.5.3.2. QC

If the QC button is selected the quadrant shown the quality control information of the selected frame (Figure 6). Main quality control keywords (CHECK keywords) are shown in the top of the panel, with a green colour if good quality (QC = 1) or red colour if bad quality (QC = 0)

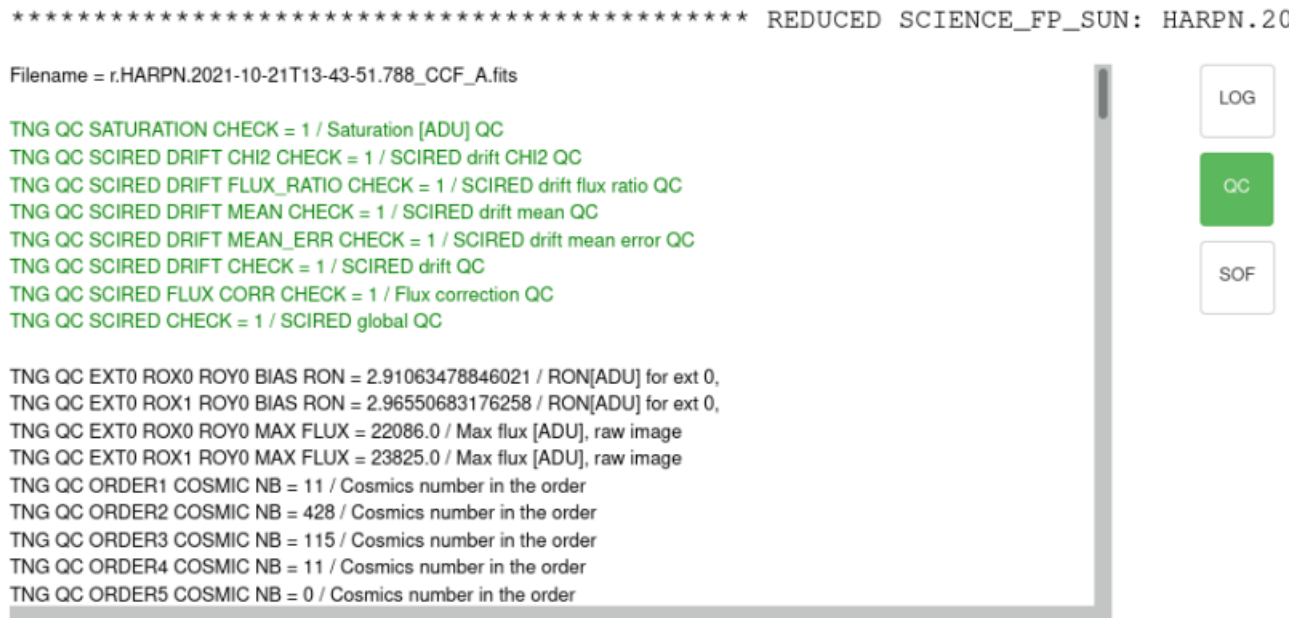


Figure 6 - Quality Control information

### 3.5.3.3. SOF

The SOF button allow you to read the Set of File (SOF) which describes all the products that are used to reduce a frame. This can be used for example to see if a frame has been reduced with the most recent available products. (Figure 7).

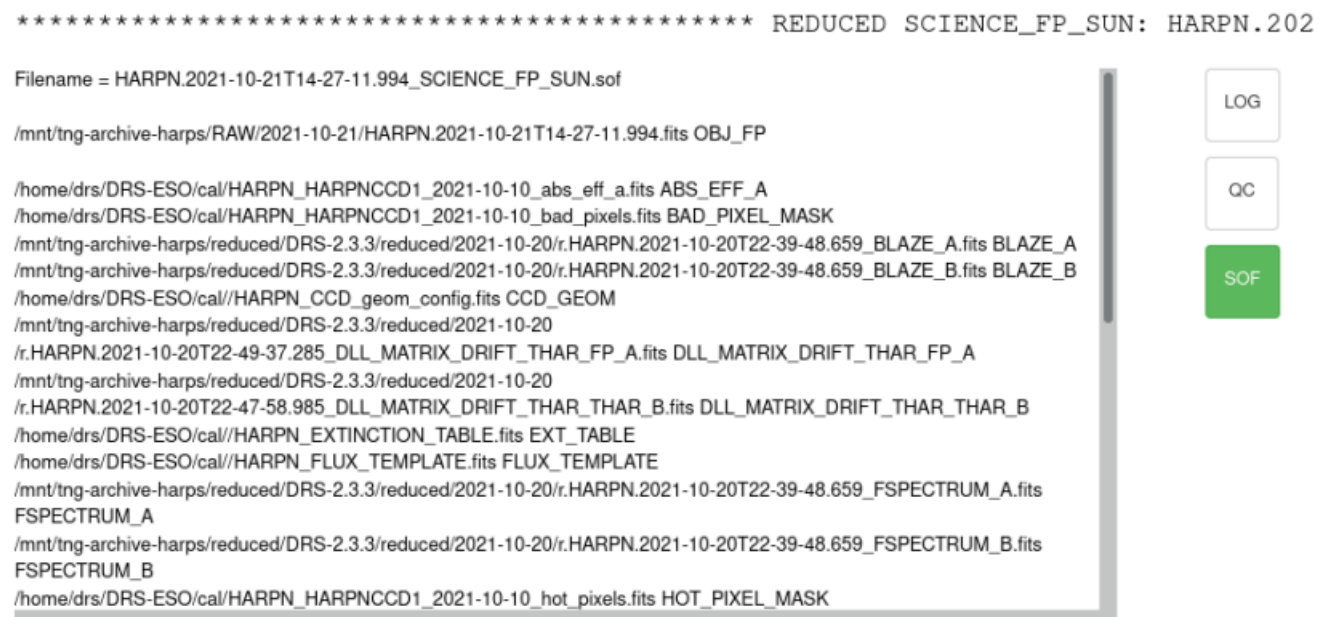


Figure 7 -



### 3.5.4. Black box: Information about the selected RAW frame (CCF, SNR, S1D, RAW)

To show the information, first you must select the frame in the **Raw Frame Box**.

The information shown in this frame depends on the button selected in the right part of the frame.

#### 3.5.4.1. CCF

The visualization of CCF, SNR, S1D are only available for SCIENCE frames, for calibration frames, there will be different info. For the moment not all the plots are available for each reduction type.

When the CCF button is selected, in this quadrant are shown several information concerning the radial velocity (RV) and the cross-correlation function (Figure 8):

- The radial velocity and the associated error (RV)
- The CCF profile (blue curve)
- The Drift
- The contrast
- The CCF FWHM

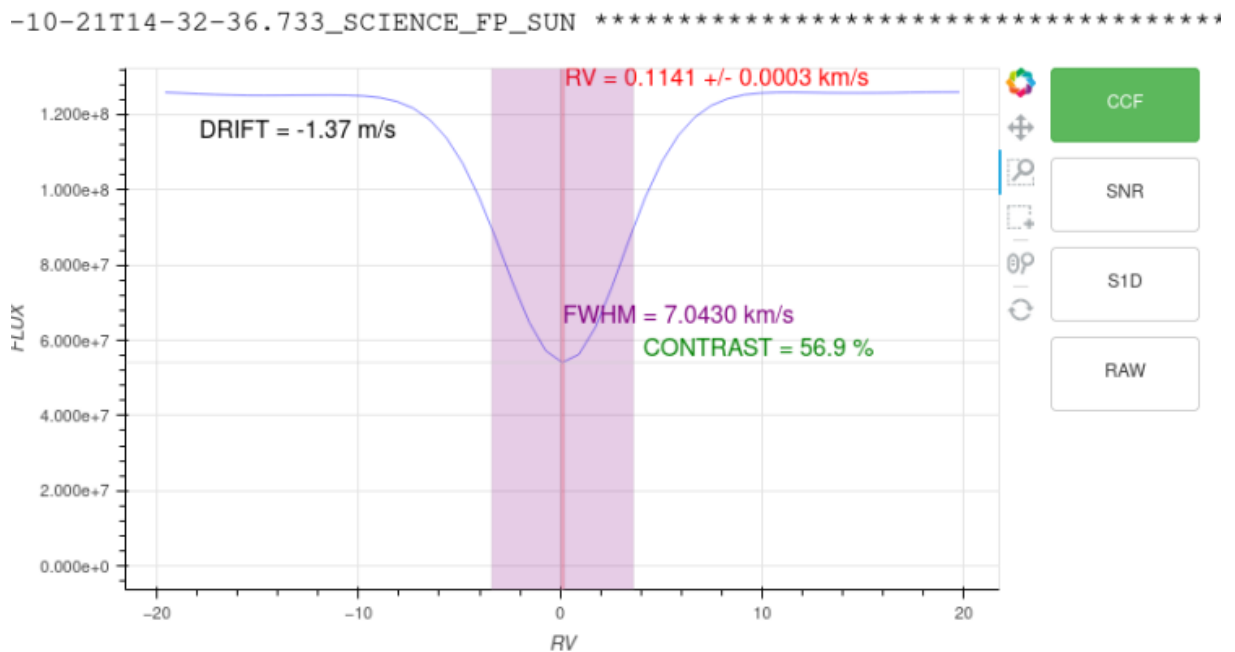


Figure 8 - Cross Correlated Function and RV information

### 3.5.4.2. SNR

By selecting the SNR button, are visualized the graphic of S/N vs Order

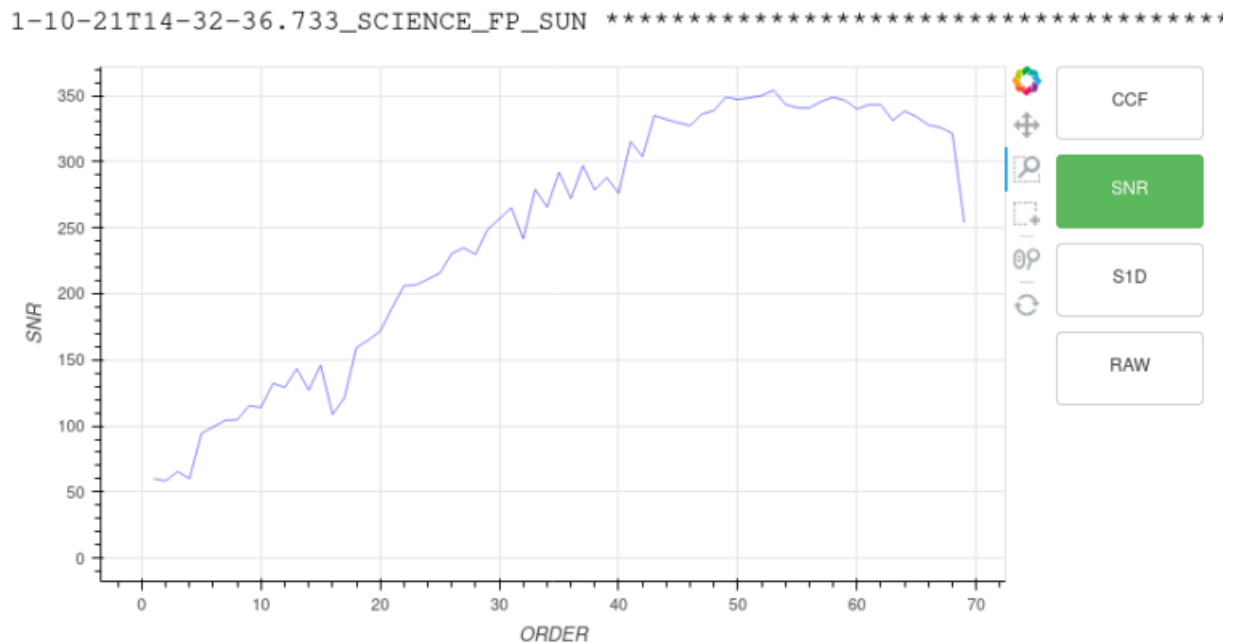


Figure 9 - S/N vs Order

### 3.5.4.3. S1D

The Extracted 1-Dimensional Spectrum is visualized if the S1D button is selected (Figure 10).

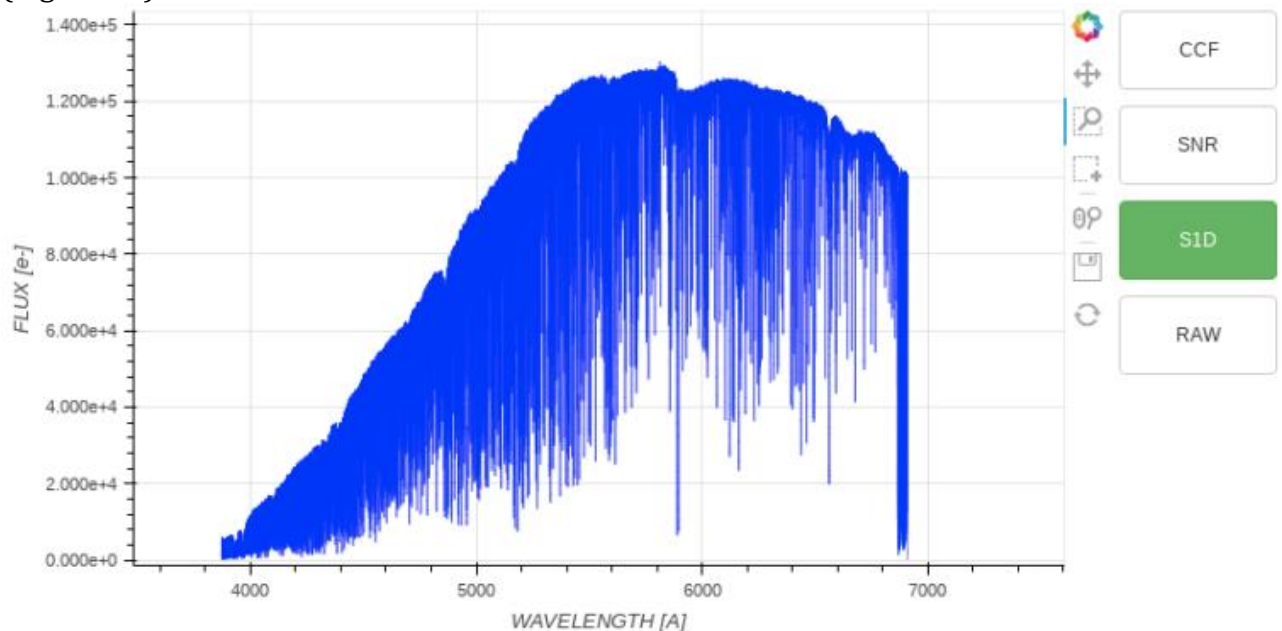


Figure 10 – Extracted 1-Dimensional Spectrum



#### 3.5.4.4. RAW

The RAW button provides the visualization of the selected RAW frame.

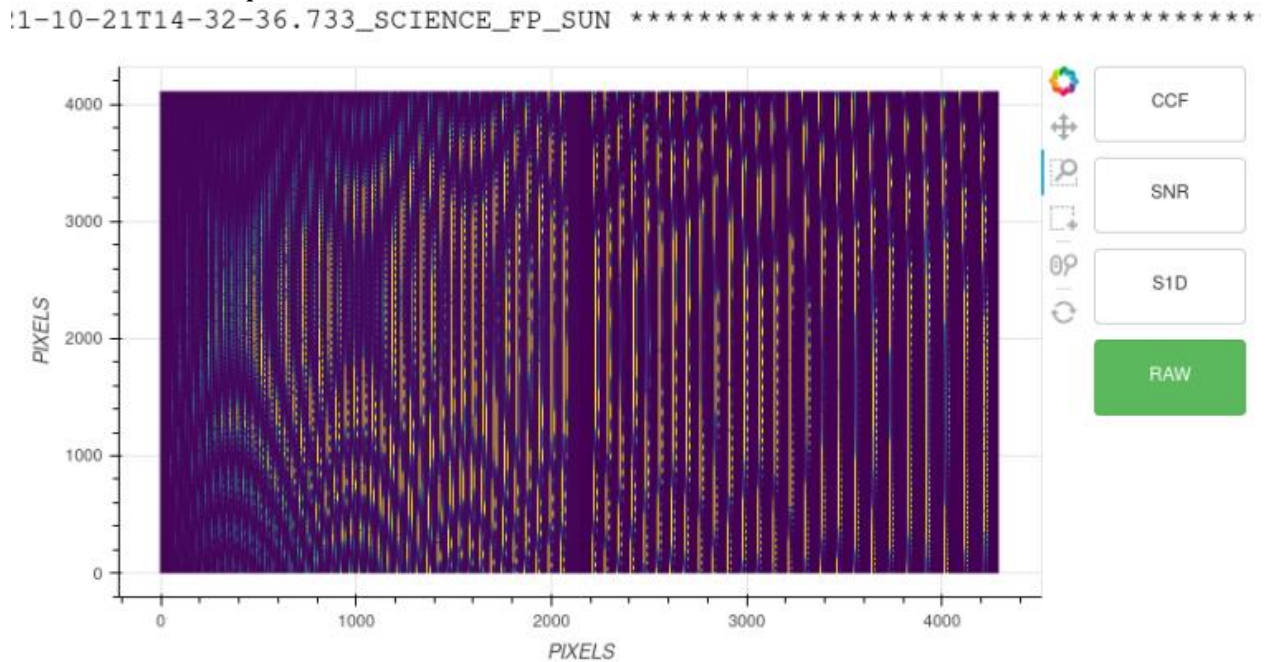


Figure 11 - RAW frame

### 3.6. Comparison between the DRS

The differences between the original DRS-32 and the ESPRESSO DRS consist in an increasing of efficiency and precision in the RV calculation. Consequently, the changes in the software imply a difference in the reduced results and in the input data needed (RV, mask to be used, fits keywords. Etc.).

The new DRS is based on the ESPRESSO pipeline and the reduced data follows the same standard.

- The masks used by the pipeline to calculate the RV was extended to more spectral types, increasing the RV precision..  
Masks available: **F9, G2, G8, G9, K2, K6, M0, M2, M3, M4, M5**
- **To correctly extract the RV of a star, it is MANDATORY to provided an estimated RV value with a precision of about a km/s** The RV calculation need the estimated value of the RV of the star (radvel value in the catalogue file or TEL.TARG.RADVEL in the NSTS setting).  
To correctly extract the RV of a star, it is MANDATORY to provide an estimated RV value (precision of a km/s is enough). The **radvel= -99999 value for an unknown RV it is no longer allowed.**
- In the fits headers the Barycentric Julian date is represented in different time coordinates:
  - In the original DRS the keyword "HIERARCH TNG DRS BJD" is represented in Universal Time Coordinate (UTC).

- In the ESPRESSO DRS the keyword “**HIERARCH TNG QC BJD**” is represented in Barycentric Dynamical Time (TDB)  
Both values are calculated at the flux-weighted mid-exposure time.

From the NSTS the observer can prepare the sequence of observation blocks of the night.

The target can be inserted directly in the NSTS or by using a catalog file that contains the objects information.

The format of the catalogue file is an ascii file and the fields separator is a TAB (ascii code = 9).

The fields of the catalogue are shown in Table 3, the mandatory fields are shown in bold format.

An example of catalog file is shown in the HARPS-N webpage:

(<http://www.tng.iac.es/instruments/harps/data/SpStdHARPSN.cat>)

**Table 3 - Catalog file entry and NSTS variables table**

Catalog name	NSTS Name	Fits Header	Column Name	Value/Unit
<b>alpha</b>	<b>TEL.TARG.ALPHA</b>	<b>HIERARCH TNG TEL TARG ALPHA</b>	<b>right ascension</b>	<b>nn:nn:nn.nn</b>
<b>delta</b>	<b>TEL.TARG.DELTA</b>	<b>HIERARCH TNG TEL TARG DELTA</b>	<b>Declination</b>	<b>nn:nn:nn.nn</b>
mualpha	TEL.TARG.PMA	HIERARCH TNG TEL TARG PMA	proper motion alpha	arcsec/year
mudelta	TEL.TARG.PMD	HIERARCH TNG TEL TARG PMD	proper motion delta	arcsec/year
<b>mv</b>	<b>TEL.TARG.MAG</b>	<b>HIERARCH TNG TEL TARG MAG</b>	<b>magnitude V</b>	<b>magnitude V</b>
bv	Not implemented	Not implemented	Bv	Bv
TypSp	<b>Not used</b>	<b>Not present</b>	spectral type	spectral type
<b>radvel</b>	<b>TEL.TARG.RADVEL</b>	<b>HIERARCH TNG TEL TARG RADVEL</b>	<b>mean radial velocity</b>	<b>KM/sec</b>
snr	S/N (550nm):		Signal/Noise	Signal/Noise at 550nm
<b>spectr</b>	<b>TEL.TARG.SPTYPE</b>	HIERARCH TNG QC CCF MASK	spectral type for the mask	F9, G2, G8, G9, K2, K6, M0, M2, M3, M4, M5
remarks	comment		Remarks	Remarks
acquisition	TPL.NAME	HIERARCH TNG TPL NAME	Acquisition template	e.g.. HARPN_ech_acq_objA
equinox	TEL.TARG.EQUINOX	HIERARCH TNG TEL TARG EQUINOX	Equinox	Equinox
<b>progid</b>	<b>OBS.PROG.ID</b>	<b>HIERARCH TNG OBS PROG ID</b>	<b>program identificator</b>	<b>es. TAC_xx</b>
<b>piname</b>	<b>OBS.PI-COI.NAME</b>	<b>HIERARCH TNG OBS PI-COI NAME</b>	<b>PI name</b>	<b>char</b>
<b>exptime</b>	<b>DET.WIN1.UIT1</b>	<b>EXPTIME</b>	<b>Exposure time</b>	<b>seconds</b>
<b>name</b>	OBS.TARG.NAME	HIERARCH TNG OBS TARG NAME	<b>Target name</b>	<b>Char</b>

### 3.7. Reduction products

The reduction products of the ESPRESSO DRS are the followings:

Reduction product	Description
S2D_A	Echelle-order extracted spectrum blaze corrected for fibre A
S2D_B	Echelle-order extracted spectrum blaze corrected for fibre B
S2D_BLAZE_A	Echelle-order extracted spectrum Without blaze correction for fibre A
S2D_BLAZE_B	Echelle-order extracted spectrum Without blaze correction for fibre B
S1D_A	Order-merged spectrum for fibre A
S1D_B	Order-merged spectrum for fibre B
S1D_FLUXCAL_A	S1D flux calibrated spectrum for fibre A
CCF_A	CCF for fibre A
CCF_B	CCF for fibre B
CCF_RESIDUALS_A	residuals from CCF computation
S2D_SKYSUB_A	S2D spectrum sky-subtracted for fibre A
S1D_SKYSUB_A	S1D spectrum sky-subtracted for fibre A
CCF_SKYSUB_A	CCF sky-subtracted for fiber A
S1D_SKYSUB_FLUXCAL_A	S1D spectrum sky-subtracted flux calibrated for fibre A

**Table 4 - Reduction product of the DRS**

The reduced files format is:

**r.HARPN.YYYY-MM-DDThh-mm-ss.sss\_ReductionProduct\_FIBER.fits**

where:

- yyyy-mm-dd = date of the observation (year, month, day)
- hh-mm-ss.sss = hour of the observation (hour, minuter, seconds)
- ReductionProduct is the name of the product (Table 4)
- Fiber can be A or B

## Appendix C – List of acronyms

ADC	Atmospheric Dispersion Compensator
AG	Auto-Guider
CCD	Charge Coupled Device
CCF	Cross Correlation Function
CFC	Continuous Flow Cryostat
CU	Calibration Unit
DFS	Data Flow System
DRS	Data Reduction Software
E2DS	Extracted 2-Dimensional Spectrum
ETC	Exposure Time Calculator
FEU	Front End Unit
FITS	Flexible Image Transport System
FWHM	<i>Full Width at Half Maximum</i>
HARPS-N	High Accuracy Radial velocity Planet Searcher in the North hemisphere
ND	Neutral Density
NSTS	New Short Time Scheduler
OB	Observing Block
RV	Radial Velocity
S1D	Extracted 1-Dimensional Spectrum
SA	Support Astronomer
SNR	Signal to Noise Ratio
TBC	To Be Confirmed
TBD	To Be defined
TBF	To be fixed
ThAr	Thorium Argon
TNG	Telescopio Nazionale Galileo
TO	Telescope Operator
UI	User Interface
VA	Visiting Astronomer