GIANO-B online data reduction software at the TNG

Harutyunyan, Avet, Rainer, Monica, Hernandez, Nauzet, Oliva, Ernesto, Guerra, Jose, et al.

Avet Harutyunyan, Monica Rainer, Nauzet Hernandez, Ernesto Oliva, Jose Guerra, Marcello Lodi, Jose San Juan, Andrea Bignamini, Adriano Ghedina, Francesca Ghinassi, Emilio Molinari, Serena Benatti, Ilaria Carleo, Riccardo Claudi, Giuseppina Micela, Andrea Tozzi, Carlo Baffa, Andrea Baruffolo, Valdemaro Biliotti, Nicolas Buchschacher, Massimo Cecconi, Rosario Cosentino, Gilberto Falcini, Daniela Fantinel, Luca Fini, Alberto Galli, Elisabetta Giani, Carlos Gonzalez, Esther Gonzalez-Alvarez, Manuel Gonzalez, Raffaele Gratton, Marcos Hernandez Diaz, Marcella Iuzzolino, Luca Malavolta, Jesus Maldonado, Livia Origlia, Ennio Poretti, Hector Perez Ventura, Alfio Puglisi, Carlos Riverol, Luis Riverol, Nicoletta Sanna, Salvatore Scuderi, Ulf Seeman, Alessandro Sozzetti, Mauro Sozzi, "GIANO-B online data reduction software at the TNG," Proc. SPIE 10706, Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation III, 1070642 (10 July 2018); doi: 10.1117/12.2312690

SPIE.

Event: SPIE Astronomical Telescopes + Instrumentation, 2018, Austin, Texas, United States

GIANO-B Online Data Reduction Software at the TNG

Avet Harutyunyan[a], Monica Rainer[b,c], Nauzet Hernandez[a], Ernesto Oliva[b], Jose Guerra[a], Marcello Lodi[a], Jose San Juan[a], Andrea Bignamini[d], Adriano Ghedina[a], Francesca Ghinassi[a], Emilio Molinari[e,a], Serena Benatti[f], Ilaria Carleo[g,f], Riccardo Claudi[f], Giuseppina Micela[h], Andrea Tozzi[b], Carlo Baffa[b], Andrea Baruffolo[f], Valdemaro Biliotti[b], Nicolas Buchschacher[i], Massimo Cecconi[a], Rosario Cosentino[a], Gilberto Falcini[b], Daniela Fantinel[f], Luca Fini[b], Alberto Galli[a], Elisabetta Giani[b], Carlos Gonzalez[a], Esther Gonzalez-Alvarez[h], Manuel Gonzalez[a], Raffaele Gratton[f], Marcos Hernandez Diaz[a], Marcella Iuzzolino[j], Luca Malavolta[g], Jesus Maldonado[h], Livia Origlia[k], Ennio Poretti[a], Hector Perez Ventura[a], Alfio Puglisi[b], Carlos Riverol[a], Luis Riverol[a], Nicoletta Sanna[b], Salvatore Scuderi[l], Ulf Seeman[m], Alessandro Sozzetti[n], and Mauro Sozzi[b]

[a]Fundacíon Galileo Galilei INAF, Rambla José Ana Fernández Pérez, 7, 38712 Breña Baja TF, Spain
[b]INAF Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I-50125 Firenze, Italy
[c]INAF Osservatorio Astronomico di Brera, via Emilio Bianchi 46, I-23807 Merate LC, Italy
[d]INAF Osservatorio Astronomico di Trieste, Via G.B. Tiepolo 11, I-34143 Trieste, Italy
[e]INAF Osservatorio Astronomico di Cagliari, Via della Scienza 5, I-09047 Selargius CA, Italy
[f]INAF Osservatorio Astronomico di Padova, Vicolo Osservatorio 5, I-35122 Padova, Italy
[g]Università di Padova, Via 8 Febbraio 2, I-35122 Padova, Italy
[h]INAF Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, I-90134 Palermo, Italy
[i]Université de Genève, 24 rue du Général-Dufour, 1211 Genève 4, Switzerland
[j]Officina Stellare, Via Della Tecnica, 87/89, I-36030 Sarcedo VI, Italy
[k]INAF Osservatorio Astronomico di Bologna, via Gobetti 93/3, I-40129 Bologna, Italy
[l]INAF Osservatorio Astrofisico di Catania, via S.Sofia 78, I-95123 Catania, Italy
[m]Institut für Astrophysik - Georg-August Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany
[n]INAF Osservatorio Astrofisico di Torino, via Osservatorio 20, I-10025 Pino Torinese TO, Italy

ABSTRACT

GIANO-B is the high resolution near-infrared (NIR) spectrograph of the Telescopio Nazionale Galileo (TNG), which started its regular operations in October 2017. Here we present GIANO-B Online Data Reduction Software (DRS) operating at the Telescope.

GIANO-B Online DRS is a complete end-to-end solution for the spectrograph real-time data handling. The Online DRS provides management, processing and archival of GIANO-B scientific and calibration data. Once the instrument control software acquires the exposure ramp segments from the detector, the DRS ensures the complete data flow until the final data products are ingested into the science archive. A part of the Online DRS is GOFIO software, which performs the reduction process from ramp-processed 2D spectra to extracted and calibrated 1D spectra.

A User Interface (UI) developed as a part of the Online DRS provides basic information on the final reduced data, thus allowing the observer to take decisions in real-time during the night and adjust the observational strategy as needed.

Keywords: NIR high resolution spectroscopy, data reduction software, data processing, python

Send correspondence to Avet Harutyunyan, E-mail: avet@tng.iac.es

Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation III, edited by Ramón Navarro, Roland Geyl, Proc. of SPIE Vol. 10706, 1070642 · © 2018 SPIE
CCC code: 0277-786X/18/$18 · doi: 10.1117/12.2312690

1. INTRODUCTION

GIANO-B is a near-infrared (NIR) high resolution spectrograph[1,2] mounted at the Telescopio Nazionale Galileo (TNG), which provides cross-dispersed echelle spectroscopy at a resolution of ∼50000 in the 0.9-2.45μm spectral range in a single exposure.
With the aim of providing a complete solution to the real-time handling of GIANO-B observational and calibration data at the Telescope, we developed the GIANO-B Online Data Reduction Software (DRS). The Online DRS kicks in as soon as exposure ramp segments are acquired from the detector by the Instrument Control System (ICS), and manages the data processing and the storage of data products. The data are first stored locally at the telescope and then sent to the TNG data archive (Sec. 7), from where they are available for download shortly after they were acquired and processed.

2. ONLINE DRS OVERVIEW

The Online DRS dataflow is shown in Fig. 1. The Online DRS code is mainly written in `Python`*, with exception of a `fortran` procedure (see Sec. 3). For the user interface some additional web programming technologies were used (Sec. 5).

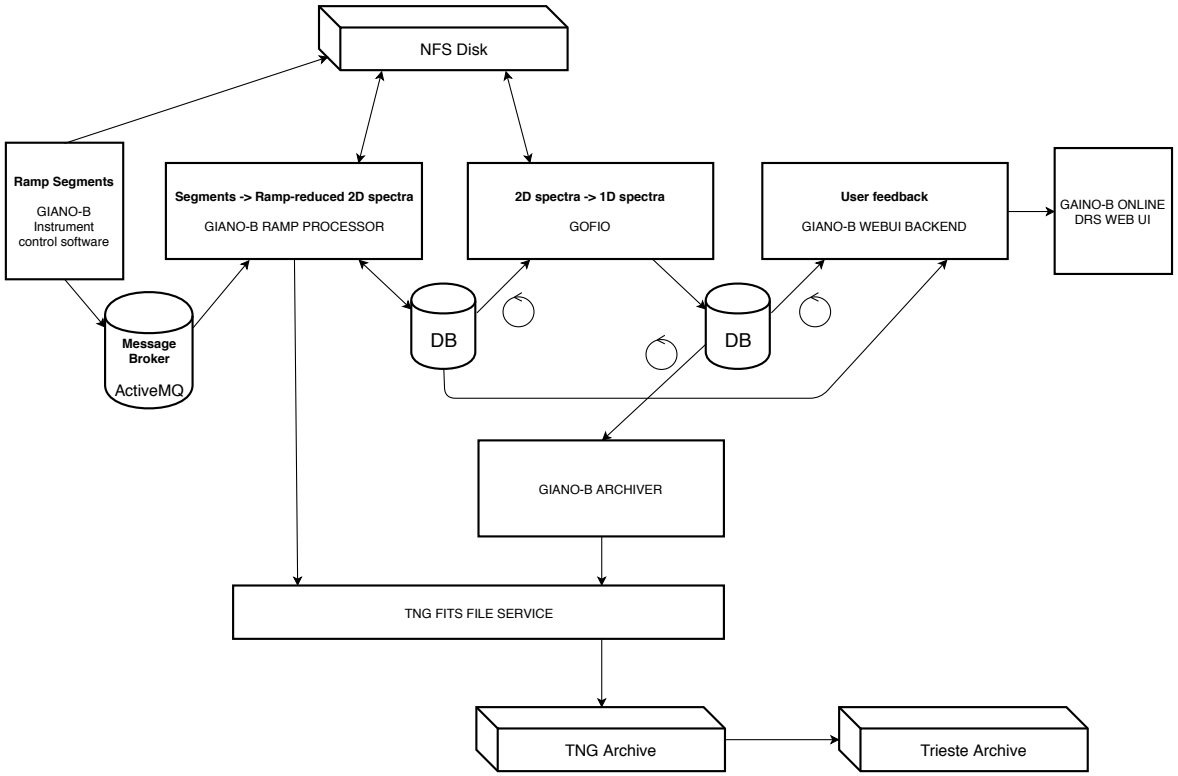

Figure 1. The Online DRS dataflow.

One of the basic ideas behind the Online DRS design is to decouple as much as possible the data handling system from that of the observation management. With this approach, the potential issues of data handling

*https://www.python.org

and processing would not interfere with the more critical instrument control or detector acquisition operations. Thus, the Online DRS and the instrument control and acquisition systems are set to operate on separate nodes. In such a context, a message-oriented middleware is particularly well-suited for providing the interaction of the two components. GIANO-B Online DRS exploits this infrastructure through a message broker, to receive information about newly acquired data from the instrument acquisition system.
The communication between the GIANO-B data acquisition system and the Online DRS is done through `STOMP`[†] protocol. These two applications use an `Apache ActiveMQ`[‡] message broker already implemented for the telescope control system at the TNG.
For reading and writing the files, GIANO-B Online DRS accesses a dedicated Network File System (NFS) storage space, created to hold all GIANO-B data. The Online DRS also makes use of `SQLite`[§] databases for its operations.
In the following sections of the text the different parts of the flowchart in Fig. 1 will be discussed more in detail.

3. RAMP PROCESSING AND 2D SPECTRA CREATION

During the exposure the GIANO-B data acquisition system carries out multiple non-destructive readouts of the detector data. The multiple read-outs are performed following Fowler sampling,[3] as this reduces the read-out noise. The readouts are performed every 10 seconds and for each of these exposure segments a FITS file is written to the disk. More information on the GIANO-B detector and its acquisition system can be found in Ref. 4.
In order to create a single file containing the entire exposure data, the ramp segments data are analysed and combined into a FITS file. This is done by the Online DRS in real-time once a complete set of ramp exposure segments is obtained. The core ramp analysis and processing is done using a `fortran` code especially developed for this aim, which follows the procedure described in Ref. 4.
The 2D spectra images created by the ramp processor are written into FITS files and stored to the NFS disk. Additionally, these files are ingested into the TNG data archive through a FITS file archive service running at the Telescope (Sec. 7). The information both on the processed images and ramp exposure segments are added to the database (Fig. 1). These database entries are further used for 1D spectra extraction, as well as for providing the corresponding feedback through the Online DRS user interface (Sec. 5).
Ramp processor does not require any start up and permanently watches for new ramp segments. The process is always kept alive via cron job.

4. 1D SPECTRA EXTRACTION

The reduction of the ramp processed raw files and subsequent extraction of 1D spectra is done by GOFIO,[5] which uses the 2D spectra generated by the ramp processor. The real-time information on the new 2D spectra available for extraction is obtained from the database entries added by the ramp processor every time an exposure sequence data is written into a FITS file (Sec. 3).
As with ramp processing, at this step too the resulting 1D spectra are stored to the NFS disk, while the information on these spectra together with processing success/failure status is added to the database (see Fig. 1). The 1D spectra extraction has to be started-up and shut-down, which can be done in particular through the user interface (Sec. 5).

5. USER INTERFACE

We opted for a Web-based User Interface (Web UI) for GIANO-B Online DRS to benefit from the access flexibility it provides. Also, Web UI enables the separation of the user interface of the data processing from the data themselves, avoiding direct data access potential drawbacks. The interface is available throughout the local network at the telescope and benefits from the gigabit-fast connection between the web server and client browsers.

[†] https://stomp.github.io/
[‡] http://activemq.apache.org/
[§] https://www.sqlite.org

The Web UI is delivered by `nginx`[¶] HTTP server, while both the UI back- and front-end are developed using `Django`[‖] Python Web framework. `nginx` requests are forwarded to the Framework via WSGI[**], which is provided by `uWSGI`[††]. Additionally, the usual `HTML/CSS/JavaScript` combination is used for the front end construction.

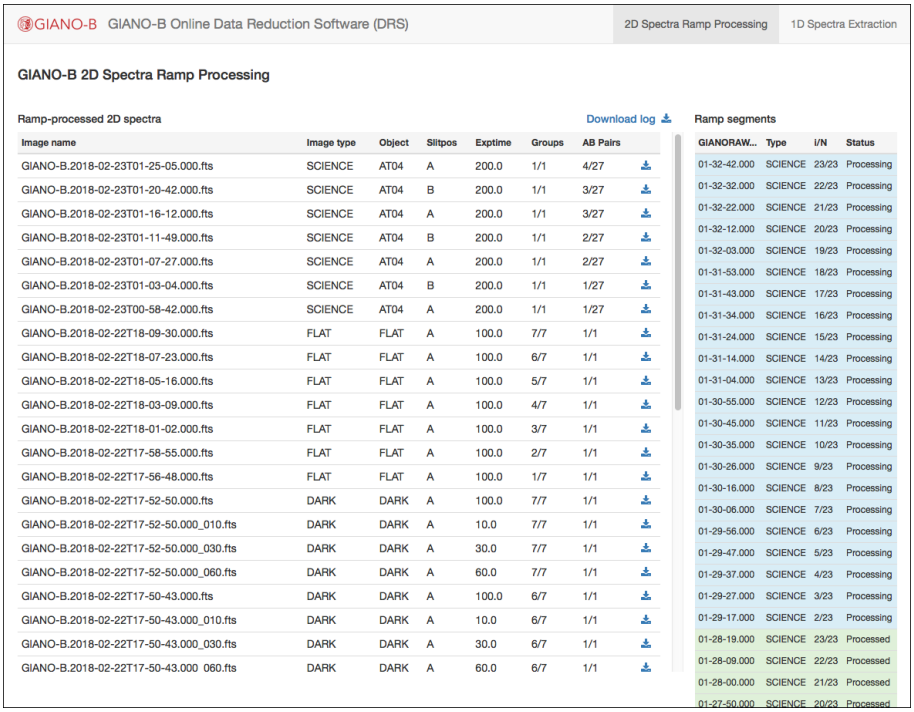

Figure 2. The 2D Spectra Ramp Processing tab Web UI.

The Web UI consists of two main sections accessed through tabs. "2D Spectra Ramp Processing" (Fig. 2) shows the progress of the 2D spectra creation through real-time ramp processing as described in Sec. 3. No action has to be carried out by the user in order turn on the ramp processing, this process is always active watching for new ramp segments.
If necessary (i.e. for inspection), the ramp-processed spectra files can be individually downloaded. Also, the contents of the ramp-processed 2D spectra table can be downloaded as a text file.
"1D Spectra Extraction" (Fig. 3) displays the state of the calibration and scientific spectra processing. Unlike the ramp processing, the spectra extraction has to be explicitly turned on. A `node.js`[‡‡] application was developed to enable the spectra extraction process start-up and shut-down from the Web UI.

Beside showing basic information on the extracted spectra (e.g. S/N in different spectral regions), the Web UI allows individual download of the extracted 1D spectra. Also, the spectra can be plotted on an overlay (Fig. 4). The plots are done on client side and are developed using `plotly.js`[§§].

[¶] https://nginx.org/
[‖] https://www.djangoproject.com/
[**] https://wsgi.readthedocs.io/
[††] https://uwsgi-docs.readthedocs.io/
[‡‡] https://nodejs.org/
[§§] https://plot.ly/javascript/

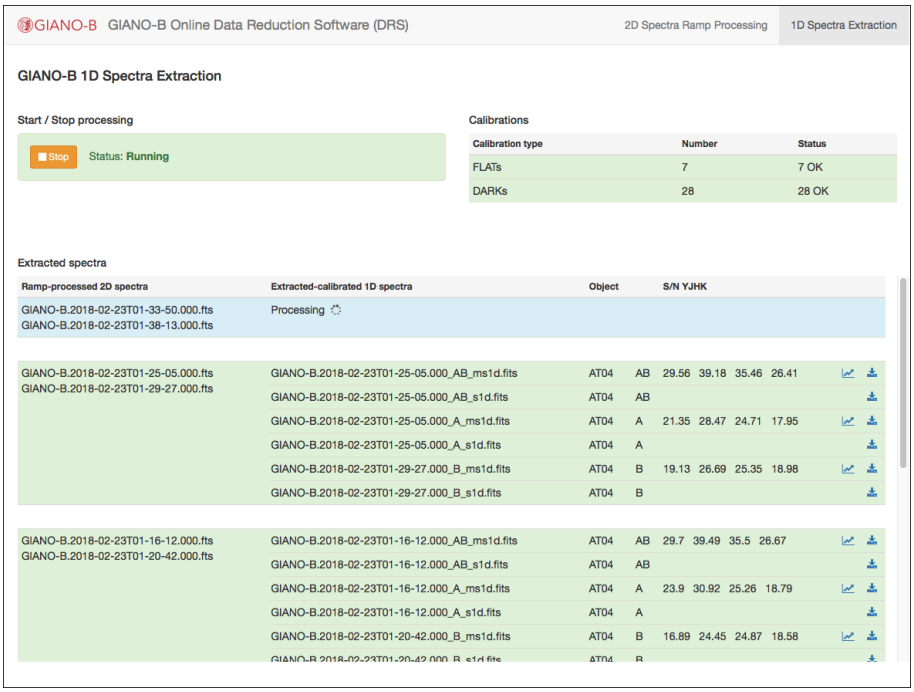

Figure 3. 1D Spectra Extraction Tab of the Web UI showing spectra processing running during a typical observing night.

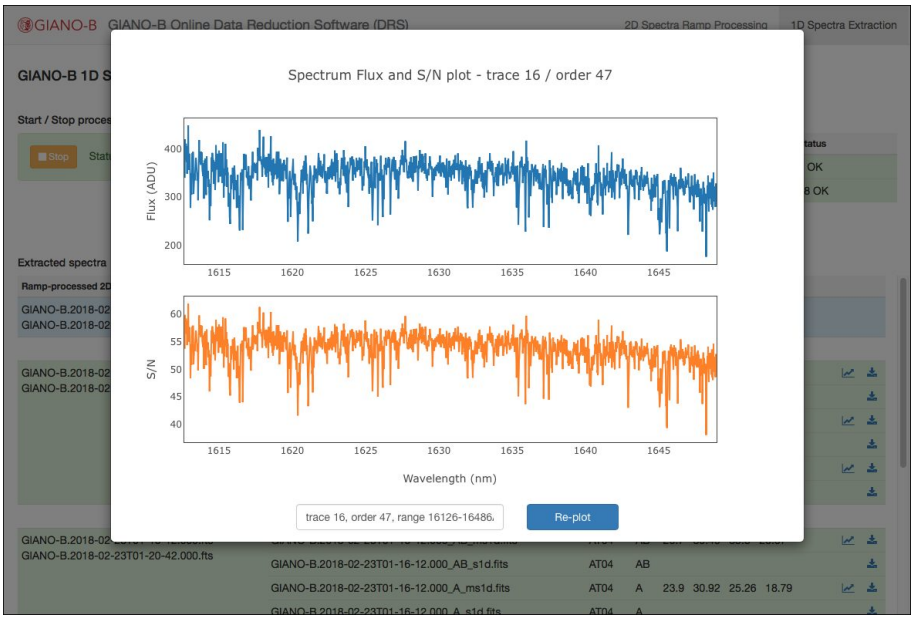

Figure 4. The plot overlay window of the Web UI.

6. DATA ARCHIVING

After the GIANO-B data are acquired and processed, they are first archived locally at the TNG. Then, the data are sent to the TNG public data archive at the Italian center for Astronomical Archives[¶¶], from where they are available to the community for downloading. The sync times between the two nodes are typically around 20 minutes.

[¶¶] http://archives.ia2.inaf.it/tng/

At the TNG side, a common HTTP service of the FITS data archive ingestion (FITS File Service - FFS) is available, which has been used for archiving of the data of all the TNG instruments. The GIANO-B Online DRS archives 2D and 1D spectra FITS data using the FFS. The access to the FFS is accomplished through a specifically developed Python client to the service. The FITS files with 2D data are archived directly by the ramp processor as soon as they are created (Sec. 3). The 1D spectra are archived shortly after their creation by a dedicated process watching for newly extracted spectra.

7. FUTURE WORK

GIANO-B Online DRS has been operating at the TNG from March 2018, without any stability issues or failures so far. That said, fast development timescales were a priority and for some of the parts of the system the implemented solutions were not the most optimal. In fact, the system can probably benefit from certain more efficient solutions, and the future work we envisage will possibly go towards the implementation of those improvements. Even if the Online DRS works within the local network and virtually has no limitation in moving large amounts of data on frequent requests, we will change from polling to event-driven approach. Beside of the evident efficiency gains, this will also simplify the overall system architecture. In particular, technologies like Server-Sent Events (SSE)[***] will be considered for this.
Other updates may include the fortran code (Sec. 3) translation to Python, while still ensuring fast array manipulations (e.g. via `numpy`[†††]). Also, overall code translation from Python 2.x to Python 3.x is considered.

REFERENCES

[1] Oliva, E., Origlia, L., Maiolino, R., Baffa, C., Biliotti, V., Bruno, P., Falcini, G., Gavriousev, V., Ghinassi, F., Giani, E., Gonzalez, M., Leone, F., Lodi, M., Massi, F., Mochi, I., Montegriffo, P., Pedani, M., Rossetti, E., Scuderi, S., Sozzi, M., and Tozzi, A., "The GIANO spectrometer: towards its first light at the TNG," in [*Ground-based and Airborne Instrumentation for Astronomy IV*], *Proc. SPIE* **8446**, 84463T (2012).

[2] Origlia, L., Oliva, E., Baffa, C., Falcini, G., Giani, E., Massi, F., Montegriffo, P., Sanna, N., Scuderi, S., Sozzi, M., Tozzi, A., Carleo, I., Gratton, R., Ghinassi, F., and Lodi, M., "High resolution near IR spectroscopy with GIANO-TNG," in [*Ground-based and Airborne Instrumentation for Astronomy V*], *Proc. SPIE* **9147**, 91471E (2014).

[3] Fowler, A. M. and Gatley, I., "Demonstration of an algorithm for read-noise reduction in infrared arrays," *ApJ* **353**, L33 (1990).

[4] Oliva, E., Biliotti, V., Baffa, C., Giani, E., Gonzalez, M., Sozzi, M., Tozzi, A., and Origlia, L., "Performances and results of the detector acquisition system of the GIANO spectrometer," in [*High Energy, Optical, and Infrared Detectors for Astronomy V*], *Proc. SPIE* **8453**, 84532T (2012).

[5] Rainer, M., Harutyunyan, A., Carleo, I., Oliva, E., Benatti, S., Bignamini, A., Claudi, R., Gonzalez-Alvarez, E., Sanna, N., Ghedina, A., Micela, G., Molinari, E., Tozzi, A., Baffa, C., Baruffolo, A., Biliotti, V., Buchschacher, N., Cecconi, M., Cosentino, R., Falcini, G., Fantinel, D., Fini, L., Galli, A., Ghinassi, F., Giani, E., Gonzalez, C., Gonzalez, M., Gratton, R., Guerra, J., Hernandez Diaz, M., Hernandez, N., Iuzzolino, M., Lodi, M., Malavolta, L., Maldonado, J., Origlia, L., Perez Ventura, H., Puglisi, A., Riverol, C., Riverol, L., San Juan, J., Scuderi, S., Seemann, U., Sozzetti, A., and Sozzi, M., "Introducing GOFIO: a DRS for the GIANO-B near-infrared spectrograph," in [*Ground-based and Airborne Instrumentation for Astronomy VII*], *Proc. SPIE* **TBD**, TBD (2018).

[***] http://www.w3.org/TR/eventsource/
[†††] http://www.numpy.org