GIANO cookbook for proposers

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About this document

This document is intended as a quick guide for GIANO proposal preparation in response to the 2015A Call for proposals issued by the TNG, where GIANO is offered for the first time to the users for regular observations.
The document contains a brief description of the instrument characteristics and the echellogram format, first estimates of performances and recommended integration times as inferred during the Commissioning and Science Verification runs performed in 2013 and 2014.

1.0 Introduction

GIANO is the near IR high resolution spectrograph mounted at the Nasmith A focus of the TNG.
The instrument provides cross-dispersed echelle spectroscopy at a resolution of 50,000 over the 0.95 – 2.45 micron spectral range in a single exposure. It is fiber-fed with two fibers of 1 arcsec angular diameter at a fixed angular distance of 3 arcsec on sky.
GIANO has one observing mode at R~50,000 and it can acquire spectra either of astrophysical objects and sky simultaneously, or of calibration lamps (halogen for flat-field and U-Ne for wavelength calibration) and dark frames. The main parameters of the GIANO detector and spectral characteristics are summarized in Table 1.
More information and detailed documentation on the instrument can be found in the GIANO webpage http://www.bo.astro.it/giano/GIANO/Documents.html.

Table 1: *Parameters of the GIANO detector and spectral characteristics.*

Detector	HAWAII-2 2048x2048
Pixel size	18 microns, 0.25 arcsec on sky
Gain	2.2 e-/ADU
Readout Noise	5 e-
Dark Current	0.05 e-/s/pixel
Wavelength Coverage	0.95 - 2.45 microns (complete coverage up to 1.72 microns, see Sect. 2.0)
Spectral Resolution	50,000
Fiber size	85 microns, 1.0 arcsec on sky
Slicer	2x

2.0 The GIANO echellograms

The GIANO echellogram (see Figures 1-3) has a fixed format and includes the orders from 32 to 80, covering the 0.95-2.45 micron wavelength range.
It has a full spectral coverage up order 45, while at lower orders the spectral coverage is progressively reduced down to 75% at order 32 (see Table 2). Due to the image slicer, each 2D frame contains four tracks per order (two per fiber).

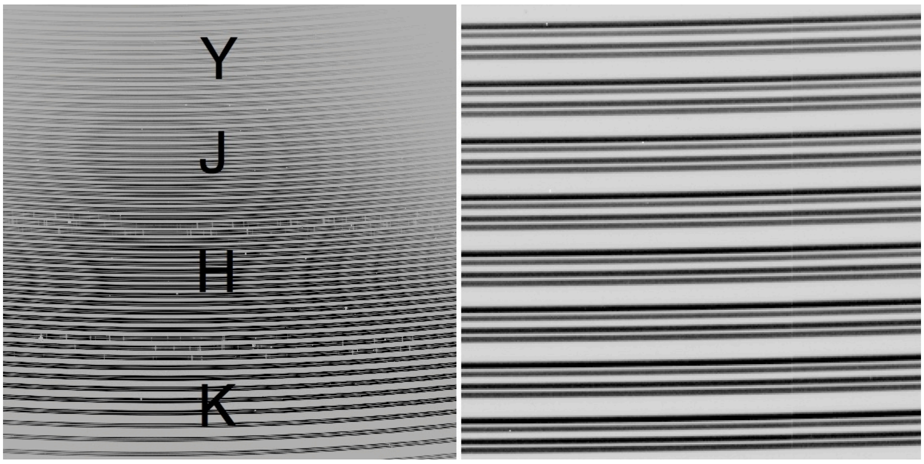

Figure 1. *GIANO 2D-spectrum of the halogen lamp used as flat-field. Left panel: the whole echellogram. Right panel: a zoomed view of the echellogram, where for each order the four tracks corresponding to the two sliced fibers are better visible.*

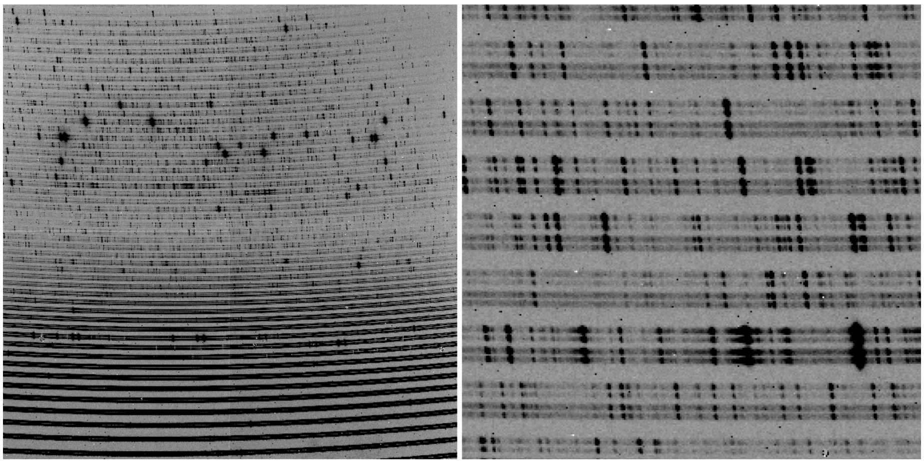

Figure 2. *GIANO 2D-spectrum of the U-Ne lamp. Left panel: the whole echellogram. Right panel: a zoomed view of the echellogram, where some Ne (the brightest) and many (fainter) U lines are visible.*

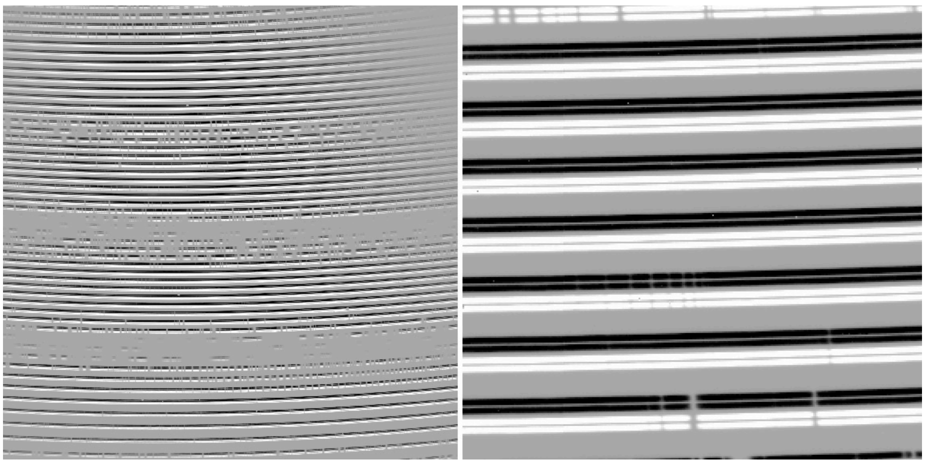

Figure 3. *GIANO nodded (A-B) 2D-spectrum of a bright star. Left panel: the whole echellogram. Right panel: a zoomed view of the echellogram, where for each order the four tracks corresponding to the two sliced A (positive) and B (negative) fibers are better visible.*

Table 2: *GIANO echellogram parameters: wavelengths are in Angstroms and in vacuum.*

# order	λ_0	λ_{min}	λ_{max}	$\Delta\lambda$
32	23974	23699	24224	0.256
33	23247	22979	23490	0.249
34	22562	22302	22799	0.242
35	21917	21664	22146	0.235
36	21308	21062	21531	0.229
37	20731	20492	20948	0.222
38	20185	19952	20396	0.217
39	19667	19440	19872	0.211
40	19174	18953	19375	0.206
41	18706	18490	18902	0.201
42	18260	18049	18451	0.196
43	17835	17629	18021	0.191
44	17429	17228	17611	0.187
45	17041	16844	17219	0.183
46	16670	16478	16844	0.179
47	16315	16126	16486	0.175
48	15974	15790	16142	0.172
49	15648	15467	15812	0.168
50	15334	15157	15495	0.165
51	15033	14860	15191	0.161
52	14744	14573	14898	0.158
53	14465	14298	14616	0.155
54	14197	14033	14345	0.152
55	13938	13777	14084	0.150
56	13689	13531	13832	0.147
57	13448	13293	13589	0.144
58	13216	13063	13354	0.142
59	12991	12841	13127	0.140
60	12774	12627	12908	0.137
61	12564	12419	12696	0.135
62	12361	12219	12491	0.133
63	12165	12024	12292	0.131
64	11974	11836	12100	0.129
65	11790	11654	11913	0.127
66	11611	11477	11732	0.125
67	11437	11305	11557	0.123
68	11268	11138	11387	0.121
69	11105	10977	11221	0.119
70	10946	10819	11060	0.118
71	10791	10667	10904	0.116
72	10641	10518	10753	0.114
73	10495	10374	10605	0.113
74	10353	10233	10461	0.111
75	10214	10096	10321	0.110
76	10080	9963	10185	0.108
77	9948	9833	10053	0.107
78	9821	9707	9923	0.106
79	9696	9584	9797	0.104
80	9574	9464	9675	0.103

3.0 GIANO Performances

First estimates of the overall GIANO performances (spectral accuracy and sensitivities), as measured during the Commissioning and Science Verification runs of 2013 and 2014, are summarized in Table 3.

Table 3: *GIANO spectral accuracy and sensitivities.*

Wavelength calibration[1] accuracy with U-Ne lamp	300 m/s (r.m.s)
Radial velocity[2] accuracy with telluric lines	7 m/s (r.m.s)
Maximum S/N[3] on flatfield (about photon-noise limited)	~1000 (Y,J), ~300 (H,K)
Maximum S/N[3] on stars (limited by fiber modal noise)	~70 (Y,J), ~50 (H,K)
Zero point (J-band, Vega mag for 1 ADU/s)	10.1
Zero point (H-band, Vega mag for 1 ADU/s)	10.3
Zero point (K-band, Vega mag for 1 ADU/s)	10.2
Limiting magnitude (z-band, Vega mag) of the guiding camera[4]	15

Notes:

[1] The optimal **wavelength solution** uses ~500 U-Ne lines distributed over all orders and provides a wavelength calibration accuracy of ~300 m/s equivalent to ~1/10 of a pixel (r.m.s). This solution has been also cross-checked over about 300 OH and O_2 atmospheric emission lines as well as some telluric features in the observed spectra, for which accurate laboratory and/or theoretical wavelengths are available.

[2] **Radial velocities** are obtained by cross correlating observed and reference lines on single orders and deriving corresponding CCFs; the latter are then weighted-summed. Internal errors amount to 3-5 m/s and are ultimately limited by the uncertainty in the stellar radial velocity and by the radial velocity signal of the CCF, while the rms scatter from different exposures of the same star amounts to 7 m/s. These errors do not depend on the spectral type of the star.

[3] Fibers suffers of **modal noise**, whose amplitude increases with increasing wavelength. GIANO uses a mechanical agitator to decrease the effect of fiber modal noise on the spectra. This mechanism works quite well for diffuse sources like the calibration lamps: the residual noise in the K-band drops from ~2% (without agitator) to ~0.3% (with agitator). However, when observing scientific targets (e.g. stars), the modal noise is amplified by effects related to the non-uniform illumination of the fiber, which also depends on the seeing conditions and on the tracking/guiding performances of the telescope. The maximum signal-to-noise achievable in the K-band is about 20 (without fiber-agitator) and 50 (with fiber-agitator). The maximum signal-to-noise is slightly higher at shorter wavelengths.

[4]The **guiding is performed on the object itself** by using a CCD camera mounted inside the GIANO interface box, which receives red light (850-950 nm, about the z band) from a dichroic filter. Hence, **for a proper guiding, targets must be brighter than z~15 mag.**

4.0 Observations and recommended exposure times

Observations of science targets are performed by nodding-on-fiber (see Figure 3), i.e. target and sky are taken in pairs and alternatively acquired on fiber A and B (AB cycles), respectively, for an optimal subtraction of the detector noise and background.
From each pair of exposure an (A-B) 2D-spectrum will be computed (see Figure 3). The positive (A) and negative (B) spectra of the target star will be then extracted and summed together to get a final, 1D wavelength-calibrated spectrum with the best possible signal-to-noise ratio.
Calibrations (dark, flat and U-Ne frames) can be taken in day-time.
Recommended on-source integration times to reach S/N~50 per spectral pixel (about modal-noise limited) for stars of different magnitudes are listed in Table 4, and overheads in Table 5.

Table 4: *Recommended on-source integration times.*

Target Vega magnitudes	**On source integration times (seeing <1 arcsec)**
JHK < 3	200 sec = 1AB cycle with 100sec on A and 100sec on B
3 <= JHK < 6	600 sec = 1AB cycle with 300sec on A and 300sec on B
6 =< JHK < 7	1200 sec = 2AB cycles with 300sec on A and 300sec on B
7 =< JHK < 8	1800 sec = 3AB cycles with 300sec on A and 300sec on B
8 =< JHK < 9	2400 sec = 4AB cycles with 300sec on A and 300sec on B
9 =< JHK < 10	3600 sec = 6AB cycles with 300sec on A and 300sec on B

Notes:
1) Allowed detector integration times (DIT) on individual fibers are as follows: 10, 30, 60, 100, 200, 300 sec. Recommended DITs for most applications are 100s (JHK<3) and 300s (JHK>3).
2) For sources with JHK>10 Vega mag, the achievable S/N strongly depends on the seeing and sky transparency. Recommended exposure times are >1.5hr, i.e. >9AB cycles with 300sec on A and 300sec on B.
3) In case of bad seeing (>1.0 arcsec) spectra of stars with JHK < 9 can still be acquired by increasing the number of AB cycles.
4) When sources have significantly different J, H and K magnitudes, one can use as reference the faintest or the most scientifically interesting one.

Table 5: *Overheads.*

Overheads	**Time**
Telescope pointing and centering	5-10 min
Detector readout and reset correction	1min per AB cycle
Telescope nodding and other settings	1 min per AB cycle