

The preslit system of GIANO-TNG

P. Bruno,^a F. Leone,^a E. Oliva,^{b,c} S. Gennari,^b I. Mochi,^b and L. Origlia^d

^a INAF – Osservatorio di Catania, via S. Sofia 78, I-95123 Catania, Italy;

^b INAF – Osservatorio di Arcetri, largo E. Fermi 5, I-50125 Firenze, Italy;

^c Telescopio Nazionale Galileo, calle A. de Abreu 70/1, E-38700 S.Cruz de La Palma, Spain;

^d INAF – Osservatorio di Bologna, via Ranzani 1, I-40127 Bologna, Italy

ABSTRACT

GIANO-TNG is an ultra-stable infrared (0.9-2.5 μm) high resolution cross-dispersed spectrometer designed to operate at a fixed position relative to the telescope axis. It therefore requires a pre-slit opto-mechanical system which takes care of field de-rotation and auto-guiding. Taking advantage of the structure already existing for SARG (the high resolution optical spectrometer of the Telescopio Nazionale Galileo, TNG) we are developing a system which provides a large (2 arcmin) field of view for offset guiding and includes, as separate and selectable elements, a gas absorption cell and a polarimetric module where the analyzers work in a collimated beam.

Keywords: Ground based infrared instrumentation, infrared spectrometers

1. INTRODUCTION

GIANO is a cross-dispersed IR high resolution ($RS=23,000$ and $R=46,000$ with a 0.5" slit) spectrometer covering most of the 0.9–2.5 μm range in a single shot. It also provides a low resolution mode ($RS\sim 400$) with complete spectral coverage from 0.75 to 2.5 μm .¹ The spectrograph is enclosed in a $\simeq 2$ m long cylindrical cryostat with $\simeq 1.3$ m diameter.² It requires an input F/11 beam and must operate at a fixed position.

This document describes the preslit system which is used to transfer the light from the Nasmyth focus of the TNG telescope to the cryogenic spectrometer.

2. OVERALL DESCRIPTION OF THE PRESPLIT SYSTEM

The preslit system is used to transfer the light from the Nasmyth focus of the TNG to a suitable position where GIANO can permanently lye without interfering with other instruments or sub-systems of the telescope. A very convenient solution is to locate the spectrometer on the right-hand side of SARG (the TNG visual high resolution spectrometer) and mount the preslit system taking advantage of the already existing mechanical structures of SARG (see Figs. 1, 2).

The main components of the preslit optics are two lens systems which create an intermediate focal plane and refocus it at F/11 onto the spectrograph entrance slit (see Fig. 3). Two flat 45° mirrors (M4, M5) are used to re-direct the optical axis vertically inside DOLORES (the TNG imager and low resolution spectrograph) and horizontally above the SARG structure.

Depending on the observing mode, three separate optical systems can be inserted in the converging beam (see Fig. 4,5). In each of these modes part of the field of view is directed to a fixed viewing/guiding camera. We plan to use a commercial InGaAs near-infrared camera with sensitivity extending to $\simeq 1.7$ μm , i.e. the system manufactured by XenICs. In such a way the observer can have a proper viewing and guiding even on extremely red objects (e.g. T-dwarfs, obscured star forming regions) which are too faint for visual CCD cameras.

The opto-mechanical elements are mounted on a commercial breadboard which can slide horizontally above the SARG upper base. This movement is accurately driven and controlled by means of a motorized actuator coupled with a linear guide (see Fig. 7). This allows a quick change of observing mode.

The three systems are confocal, i.e. no refocussing is needed when switching between them.

3. THE MAIN PRE-IMAGING OPTICS

The F/11 beam from the TNG telescope is intercepted by a 45° flat mirror (“M4”) mounted on an already existing slide, positioned inside the DOLORES instrument. The same slit also holds the first part of the preslit system for SARG. By moving this slit one can therefore direct the light to GIANO, SARG or DOLORES thus allowing a very quick interchange among the three instruments.

The beam passes through a hole/flange already existing on the DOLORES structure, and is intercepted by the entrance lens system which creates a converging beam with focal aperture F/17.7. This system consists of a BaF₂-SNPH2 detached doublet designed to work between 0.75 and 2.5 μm and to accept a sky-projected field of view of $\odot 2$ arcmin.

The first doublet is corrected for all aberrations except chromatism. Consequently, the relative alignment of the second lens system is not critical.

Just after the first doublet is a flat mirror (M5) which re-directs the light horizontally above the SARG structure (see Fig. 3).

The second lens system is located in front of the spectrometer window and transforms the diverging (and chromatic) F/17.7 beam into a corrected F/11 beam with its focus onto the spectrometer slit. It is composed by a CaF₂-SFTM16 doublet whose chromatic behaviour is perfectly adequate for recovering the chromatism introduced by the first doublet. The resulting imaging quality is excellent, with virtually all the energy falling within a sky projected angles of $0.25''$ (see left column Fig. 6).

4. PRESPLIT ELEMENTS FOR THE NORMAL HR/LR MODE

In the normal HR/LR observing mode the converging F/17.7 beam passes through an optical derotator (see Fig. 3 and upper panel of Fig. 4). This element is composed by 3 fused-silica mirrors organized/glued in a rigid structure and aligned by the manufacturer to achieve a maximum deviation of less than 30 arcsec between the input and output rays.

The derotator was manufactured by Gestione SILO s.r.l. and delivered in december 2005. The quality of the surfaces and alignment are all well within the specifications. In particular, the deviation between input and output rays is only 18 arcsec.

The light for viewing/guiding is intercepted by a 45° , 60x40 mm flat mirror with a 10x14 mm elliptical hole positioned at the intermediate focus (G1M1 in Figs. 4, 5). This mirror lets the central part of the field ($30''$ sky projected angles) going to the spectrometer, while reflects the external part (an annulus of 2 arcmin diameter, sky projected angles), to the G1L1 and G1L2 lenses (see Fig. 4). These feed the guiding camera with a F/4.7 beam. The corresponding plate scale is $12.5''/\text{mm}$, equivalent to $0.25''/\text{pix}$. Five flat bending mirrors (G1M2 through G1M5, see Figs. 4,5) are also included to achieve the necessary optical path within the available space.

5. PRESPLIT ELEMENTS FOR THE CELL MODE

A gas absorption cell is necessary to provide simultaneous wavelength reference for very accurate radial velocity measurements. The gas cell is mounted within a cylindrical dewar with 520mm length and $\leq 120\text{mm}$ diameter.³ Since there is no space to mount an optical derotator, the absorption cell mode can only be used for observing single objects.

The optics for this mode consists of 4 flat, 45° mirrors (G2M1 through G2M4, see Fig. 4) positioned before the cell in order to reproduce the same optical path as in the HR/LR mode. This implies that no refocussing is

needed when the absorption cell module is inserted.

An uncoated pellicle is also included in between G2M2 and G2M3 (see central panel of Fig. 4). This deviates 2% of the light to the viewing/guiding system which consists of a folding mirror and two glued doublets which feed the guiding camera with a F/6.9 beam. The corresponding plate scale is 8.5"/mm, equivalent to 0.17"/pix

6. THE POLARIMETRIC MODULE

This optical system is designed to create a parallel and collimated beam of $\varnothing 8.8$ mm diameter where a super-achromatic Quartz/MgF₂ $\lambda/4$ or $\lambda/2$ retarder, a Wollaston polarizer (MgF₂ prisms with 15° opening angle) and an infrasil dove-prism for field de-rotation are in sequence located. All these elements are mounted on separate rotating stages which must be synchronized to maintain the waveplate retarder at a fixed sky-projected angle, the Wollaston at a fixed angle relatively to the retarder, and the two images from the Wollaston aligned along the spectrometer slit (Fig. 8).

The optical lens system consists of two doublets. The first (PL1-2 in Fig. 3) acts as collimator, while the second (PL3-4) re-creates the converging F/17.7 beam. A system of 4 folding mirrors (G3M1-4) is used to reproduce the same optical path as in the HR/LR observing mode, i.e. no refocusing is required when the polarization module is inserted.

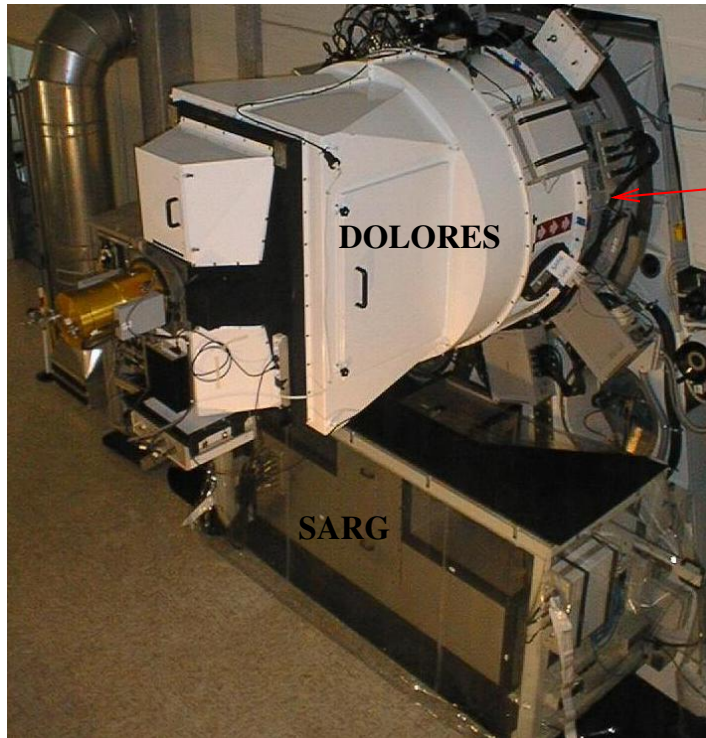
The uncoated pellicle after the G3M4 mirror re-directs $\simeq 2\%$ of the light to the guiding optics which consists of 2 glued doublets (G3L1, G3L2) which feeds the guiding camera with a F/6.2 beam through the G3M5 folding mirror (see bottom panel of Fig. 4). The plate scale is 9.5"/mm, equivalent to 0.19"/pix

7. ACKNOWLEDGEMENTS

S. Gennari is grateful to Professors G. Costamagna, M. Mutignani, G. Doglietto, F. Pacelli, V. Perri, V. Papa, A. Cassano and their staff of "Policlinico Gemelli" Hospital in Rome. Without their help he could not be in the author's list.

REFERENCES

1. Gennari, S.; Mochi, I.; Donati, S.L.; Oliva, E.; Origlia, L.; "The spectrometer optics of GIANO-TNG", this SPIE conference, paper 6269-146
2. Gennari, S.; Del Vecchio, C.; Mochi, I.; Oliva, E.; Origlia, L.; Rossettini, F.; Tomelleri, R.; Milani, D.; Liffredo, M.; Tommasin, D.; Roveta, G.; "The mechanics and cryogenics of GIANO-TNG", this SPIE conference, paper 6269-147
3. D'Amico, F.; Oliva, E.; Origlia, L.; "The gas absorption cell for GIANO-TNG", this SPIE conference, paper 6269-197



**TNG
Derotator-B**

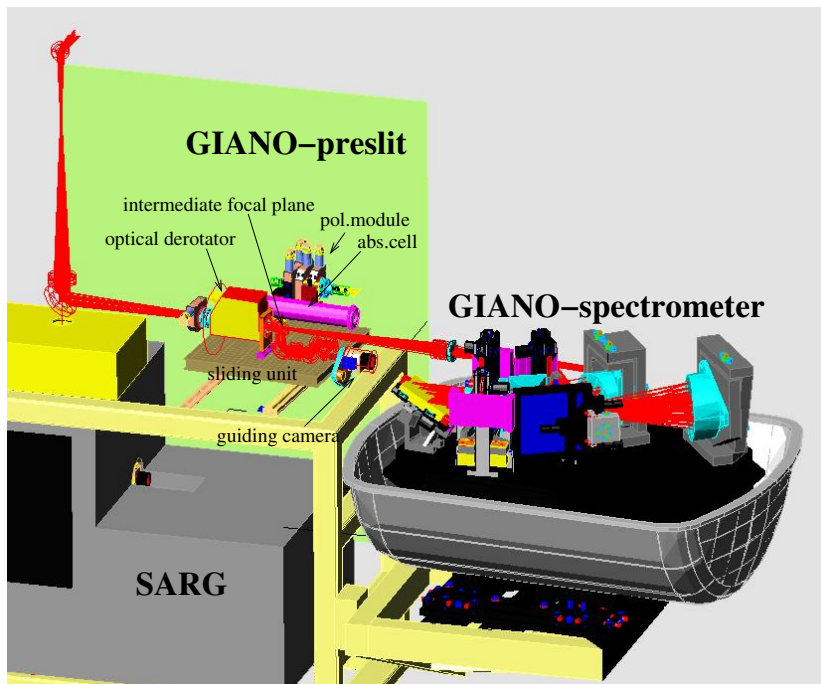


Figure 1. Upper panel: actual status of the TNG Nasmyth-B room. The optical imager and low resolution spectrometer (DOLORES) is mounted on the rotator-adaptor while the optical high resolution spectrograph (SARG) is fixed onto the telescope fork.
 Lower panel: expected status with the GIANO preslit mounted on top of SARG and the GIANO cryogenic spectrometer rigidly fixed to the telescope fork.

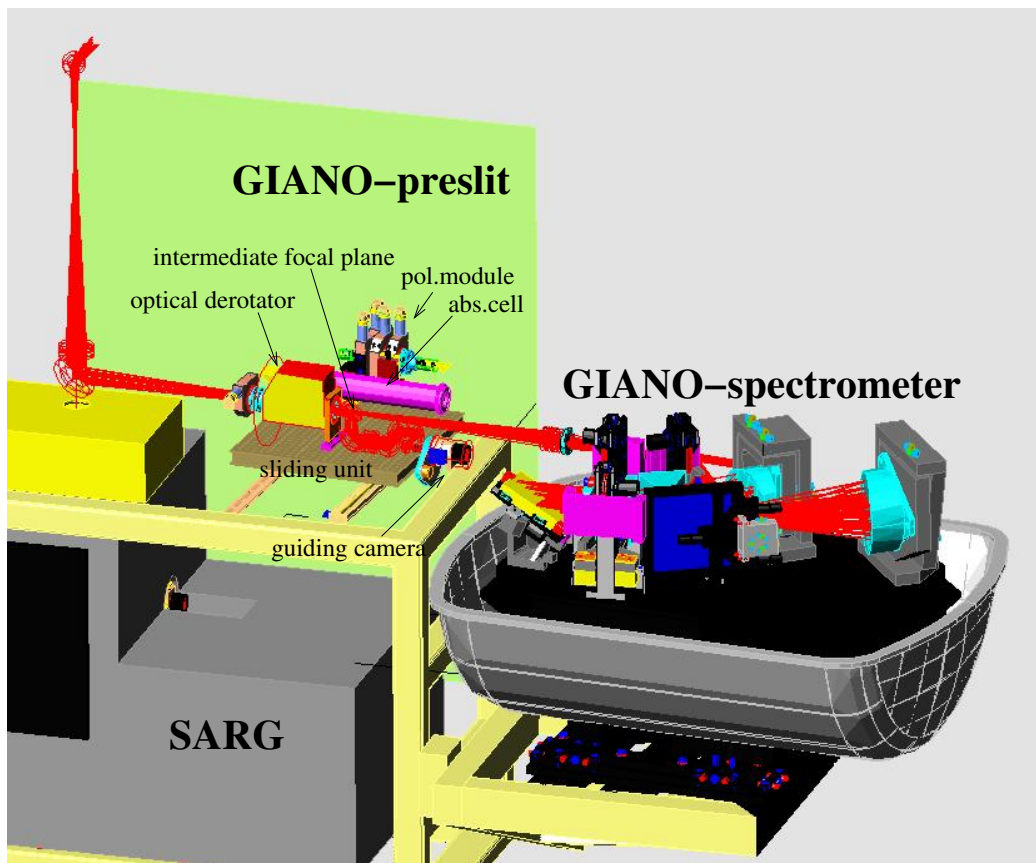


Figure 2. 3D view of the GIANO-preslit system mounted on SARG and feeding the GIANO cryogenic spectrometer.

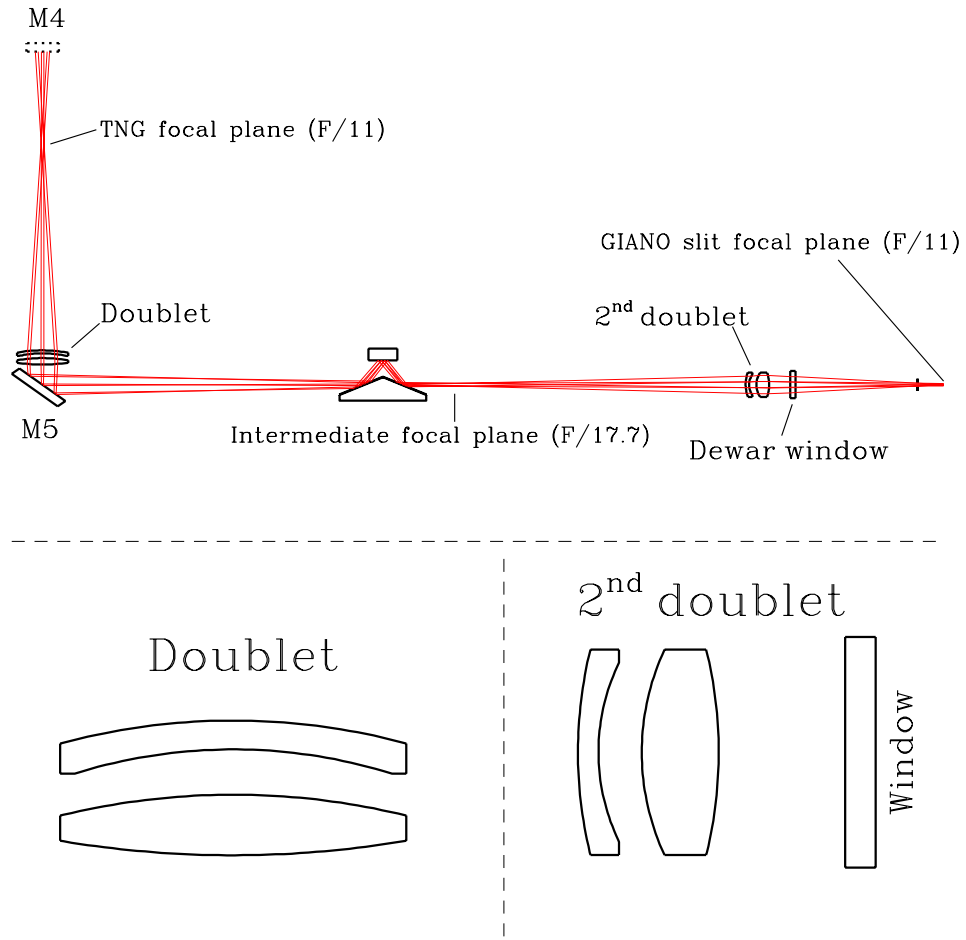


Figure 3. Overall view of the GIANO preslit optics with ray-tracing. The first 45° mirror (M4) lies inside DOLORES and is mounted on the same slide holding the SARG preslit optics. The doublet and the second mirror (M5) are mounted on a flange of the DOLORES structure. The second doublet is mounted in a cylinder attached to an adjustable structure connected to the spectrometer cryostat.

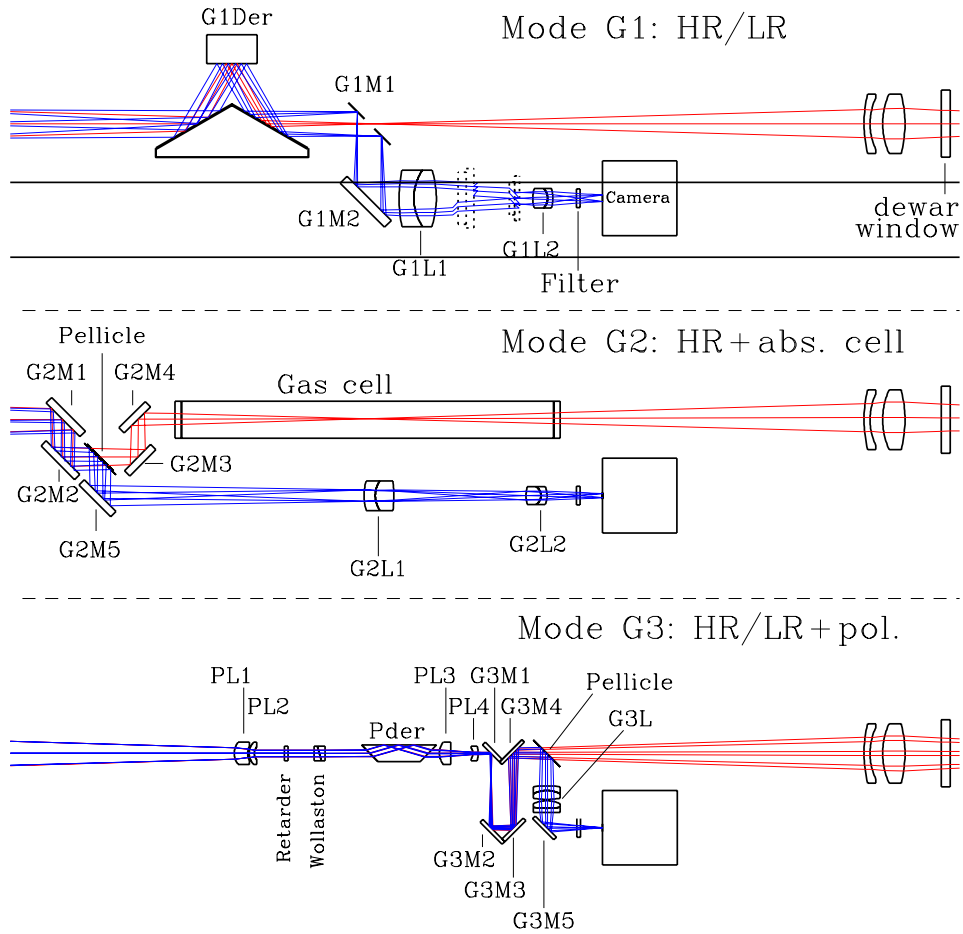
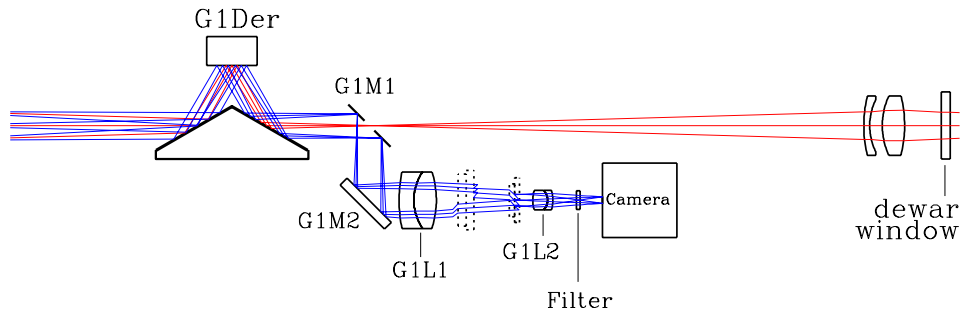


Figure 4. Side view of the horizontal part of preslit optics. The second doublet is fixed onto the spectrometer dewar in a manually adjustable structure. The camera, which also acts as guider, is a near-IR (InGaAs) commercial device fixed onto the edge of the steel structure holding SARG together with a filter wheel. The remaining optical elements (named "Gxx" and "Pxx") are mounted onto an optical bench which can slide parallel to the SARG structure and perpendicularly to the optical axis (see Fig. 7). The three systems are con-focal, i.e. no refocussing is needed when switching among them.

Mode G1, side view



Mode G1, top view

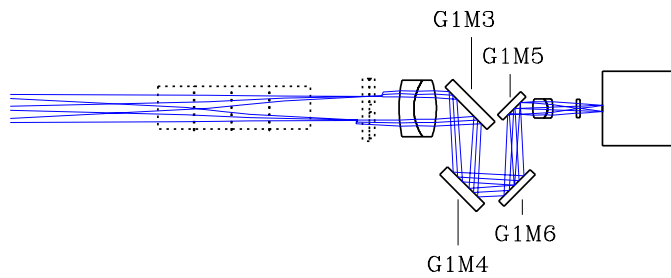


Figure 5. Side and top view of the preslit optics for the normal HR/LR mode (“G1”). The central \varnothing 30 arcsec of the field of view go to the GIANO spectrometer through the 10x14 mm elliptical hole at the center of the G1M1 mirror. The rays from the annular ring extending to 2 arcmin are reflected to the guider optics which consist of two glued doublets (G1L1, G1L2) and five 45deg flat mirrors (G1M2 to G1M6).

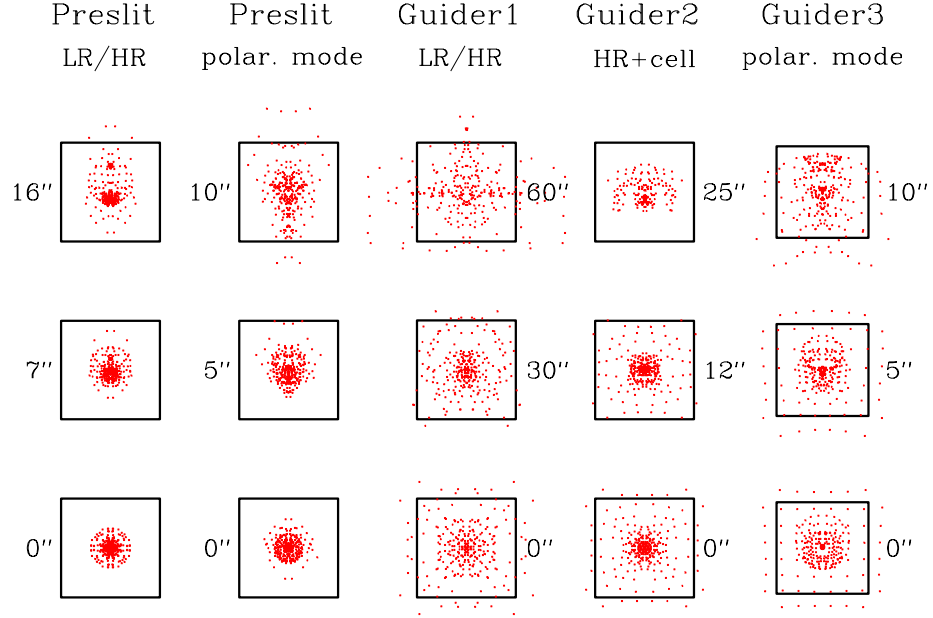


Figure 6. Spot diagrams of the preslit optics, all squares correspond to $0.25''$ sky projected angle and the numbers on the side are the distance from the field center (sky projected angles). Starting from the left:
 1^{st} column: preslit optics in the normal HR/LR mode, $\lambda = 0.75, 0.90, 1.25, 1.70, 2.40 \mu\text{m}$ with equal weights.
 2^{st} column: preslit optics in the polarimetric mode mode (bottom of Fig. 4), $\lambda = 0.90, 1.25, 1.70, 2.40 \mu\text{m}$ with equal weights.
 3^{rd} column: guider optics for the normal HR/LR mode (Fig. 4, top panel), $\lambda = 0.75, 0.90, 1.20, 1.70 \mu\text{m}$ with equal weights.
 4^{th} column: guider optics for the HR+cell mode (Fig. 4, central panel), $\lambda = 0.75, 0.90, 1.20, 1.70 \mu\text{m}$ with equal weights.
 5^{th} column: guider optics for the polarimetric mode (bottom of Fig. 4), $\lambda = 0.75, 0.90, 1.20, 1.70 \mu\text{m}$ with equal weights.

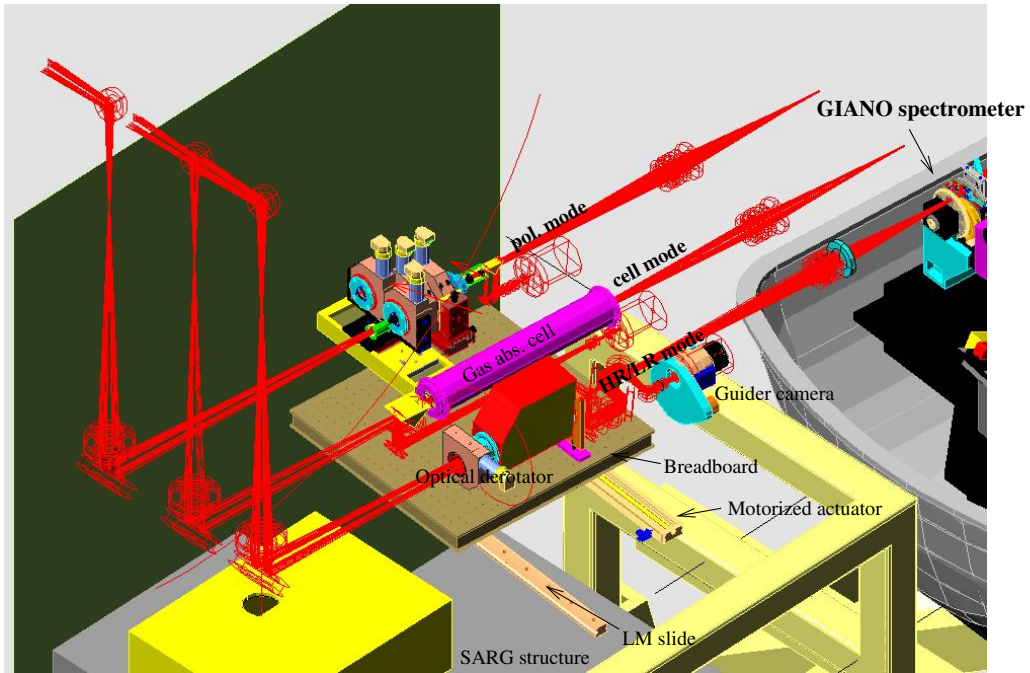


Figure 7. 3D model of the preslit opto-mechanics mounted on the SARG structure.

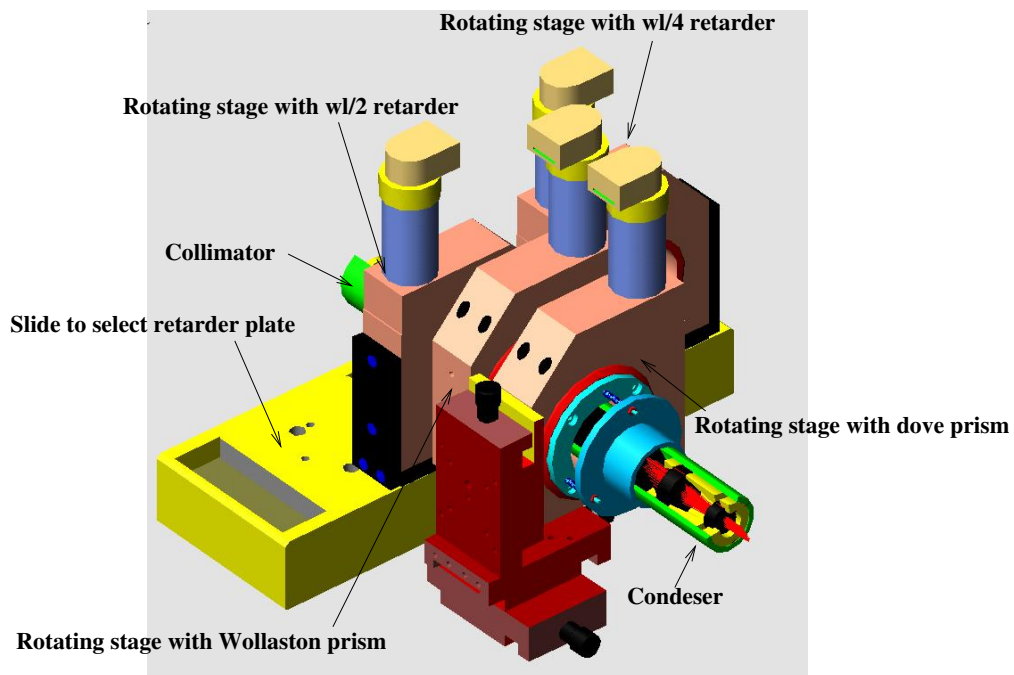


Figure 8. 3D view of the polarimetric module of GIANO which consists of a collimator (PL1-2 lenses of Fig. 4), interchangeable super-achromatic $\lambda/2$ and $\lambda/4$ retarders, a Wollaston prism, a dove-prism for field derotation and a condenser (PL3-4 lenses of Fig. 4).