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# The high resolution spectrograph of TNG

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## ABSTRACT.

The status of the high resolution spectrograph of TNG (SARG) is presented. This instrument will be in operation during early spring 2000. SARG will offer both single object and long slit (up to 30 arcsec) observing modes covering a spectral range from  $\lambda=0.37$  up to  $0.9 \mu\text{m}$ , with resolution ranging from  $R=19,000$  up to  $R=144,000$ . Cross dispersion is provided by means of a selection of four gratings and interference filters may be used for the long slit mode. A dioptric camera images the cross dispersed spectra onto a mosaic of two  $2048 \times 4096$  EEV CCDs (pixel size:  $13.5 \mu\text{m}$ ) allowing complete spectral coverage at all resolving power for  $\lambda < 0.8 \mu\text{m}$ . In order to reach a high wavelength calibration precision an iodine-absorbing cell is provided. A Distributed Active Temperature Control System (DATCS) maintains constant the temperature of all spectrograph components at a preset value. The constructive characteristics contribute to make SARG a highly competitive instrument in the following scientific goals: Planet search, asteroseismology, chemical composition of fossil remnants of very early stellar populations, studies of stellar and planetary atmospheres; studies of interstellar medium.

## 1. Introduction

SARG is the high resolution spectrograph for the Galileo National Telescope. The scientific motivation for SARG derived from the requirements given by the Italian astronomical community. It included programmes such as planet search, asteroseismology, chemical composition of fossil remnants of very early stellar populations, studies of stellar and planetary atmospheres; studies of interstellar medium. These scientific goals determined instrument specifications: a quite high spectral resolution (maximum about  $R \sim 150,000$ ), high efficiency (peak at more than 15%), rather large spectral coverage in a single shot (two shots allowing to cover the entire accessible range from 370 to 900 nm; UV was sacrificed due to budget limitations), high stability (long term stability of 5 m/s, and possibly 1 m/s over a single night). While meeting all these requirements required a complex and sophisticated instrument, design criteria also included simplicity of use and maintenance, and respect for the TNG standards and environment. The project (approved in February 1996) was scheduled as a four year project, and within a typical budget for a 4m telescope class instrument (0.85 M Euro). To realize such a

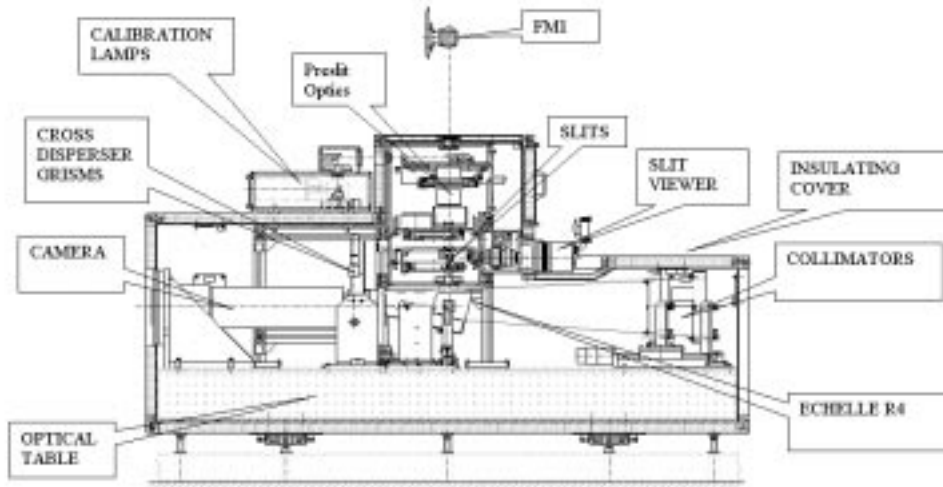


Fig. 1. Mechanical layout of SARG. The main subsystem are labeled.

complex instrument within the allowed budget, we had to take responsibility for the optical design and integration of the instrument.

Three years after its approval, SARG is under test in its own specially devoted optical laboratory in Padova, at the end of the integration and alignment phase. It will be moved to La Palma at the beginning of 2000, when the mechanical interface with the telescope will be ready.

SARG is a collaboration of the astronomical observatories of Padova (optics, mechanics, thermal control, integration, science verification, project management), Catania (controls, software, detectors), Trieste and Palermo (management and science verification). The iodine cell is realized as the doctoral dissertation programme of S. Desidera (Dept. of Astronomy, Un. Padova), with the collaboration of G. Favero (Dept. of Chemistry, Un. Padova) and A. Calì (Catania Observatory).

This document presents an updated but brief description of some of the spectrograph properties and components. Details about SARG controls, software and detectors will be given in other contribution at this meeting.

## 2. Technical Characteristics

The general layout of SARG is shown in Figure 1. SARG is mounted on an optical table rigidly attached at the fork of TNG, about 1.4 m below the Nasmyth B focus (see Figure 2). Light reaches the spectrograph through an optical train which includes three lenses (L1, L2, and L3), and a folding mirror (FM1) which redirects light exiting horizontally along the elevation axis downward to the spectrograph location. L1 and FM1 are mechanically located within DoLoRes (the TNG low dispersion spectrograph) which permanently occupies the Nasmyth B location (see Figure 3).

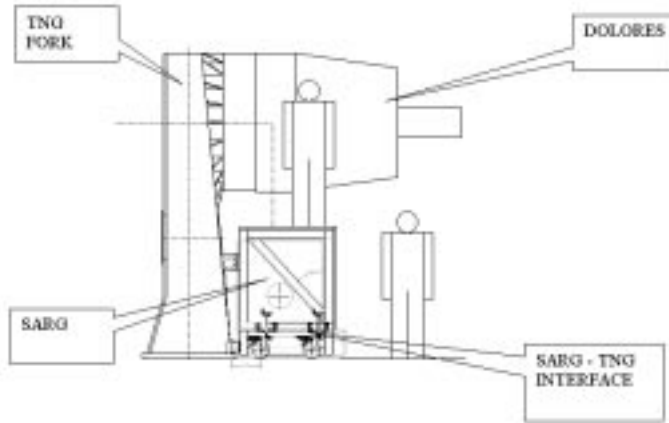


Fig. 2. SARG location on the TNG arm B.

In analogy with several modern high resolution spectrographs, SARG has a white pupil collimator. This design, coupled with the use of an R4 echelle, of grism cross dispersing elements, and of a large field, quite long focal length dioptric camera exploiting a large size detector, composed of a mosaic of  $2\ 2k \times 4k$  CCDs, pixel  $13.5\ \mu\text{m}$ , allowed a very compact and simple mechanical design. Instrument size is about  $2 \times 1 \times 1$  m, very small in view of the high spectral resolution achieved by the instrument when mounted on a 3.5 m telescope. This compact design also simplifies its thermal design: a special feature of SARG is its distributed active thermal control system (DATCS), which allows the spectrograph to have a nearly constant temperature of  $20 \pm 0.5$  C.

The preslit optics (which includes a collimated part of the optical path) and the grism cross disperser also add flexibility to SARG, allowing a variety of optical modes: multiorder short slit observations with a large spectral coverage; 30 arcsec single order long slit observations (an optical derotator allows to have an arbitrary fixed orientation of the slit projected on the sky); multiorder image slicer observations at very high spectral resolution, using a Diego modified Bowen - Walraven image slicer; high precision radial velocity observations using an  $\text{I}_2$  absorbing cell.

### 3. Optics

The preslit optics (realized by Fisba Optiks) consists of three lenses: L1 transforms the f/11 TNG beam into an f/34.4 one, allowing a suitable focal position far from the elevation axis (so that SARG would not interfere with DoLoRes). A second lens (L2) located after an intermediate (free) focal position collimates the beam, and a third f/11 lens (L3) focuses the beam onto the slit (actually, a selection of 9 different apertures located on a motorized rotating table, which allows resolution from  $R = 17,000$  up to  $R = 144,000$ ). The collimated portion of the beam is used for an Abbe-Koenig inverting

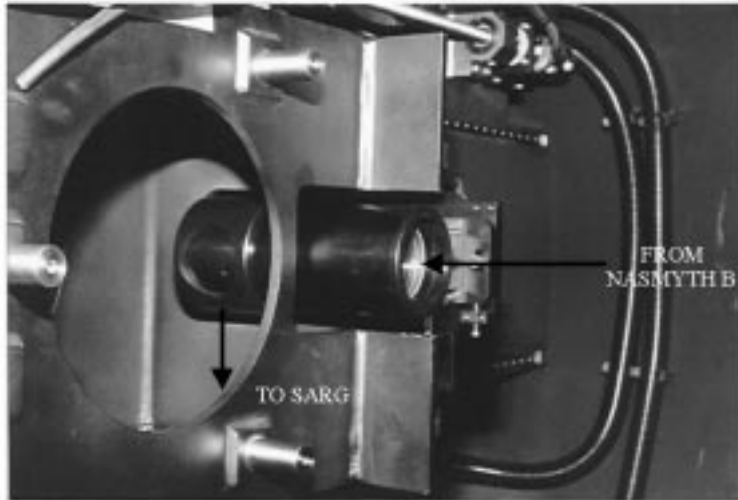


Fig. 3. Photo of FM1 within the DoLoRes input slide.

prism, which allows derotation over a field of about 30 arcsec (projected on sky). The prelit optics also include slides and wheels for neutral and coloured filters (allowing suppression of undesired light); the two calibrating systems of SARG (the lamp array, including three quartz iodine and a Th lamp; and the iodine absorbing cell); and a slit viewer assembly. This last has two modes of operation: direct imaging (using a Nikon objective) and wavefront analysis (using a Shack-Hartmann lenslet array), which allows to close the active optics loop.

The spectrograph shutter is located after the slit; thereafter, a second folding mirror (FM2) redirects light toward the  $f/11$  100 mm beam white-pupil collimator. In the first pupil image created by this system, we located the 31 gr/mm R4 grating (this choice allows a quite high  $RS$  product of  $RS = 46,000$ ) used in a quasi-Littrow configuration (off-plane angle of 0.7 degrees). A selection of grisms mounted on a rotating table are located in the second pupil image, allowing a variety of cross dispersion modes (see Table x). One further position on this table is left free, to be used for long slit observations coupled with interference filters located in the filter wheel in the prelit portion of the beam.

**Tab. 1 - Summary of Cross disperser Grism Characteristics**

	BLUE	GREEN	YELLOW	RED
Spectral Range (nm)	369–518	419–567	462–795	502–1020
Peak efficiency (Minimum separation (arcsec))	11.3	13.9	8.1	6.0

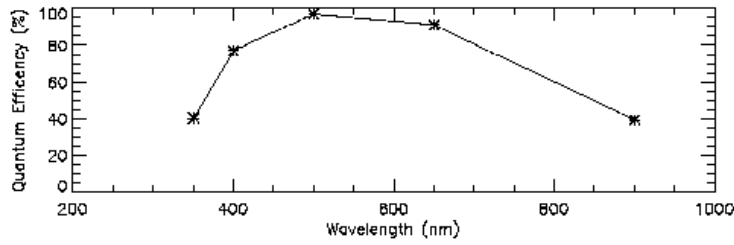


Fig. 4. Efficiency of SARG CCD as a function of wavelength.

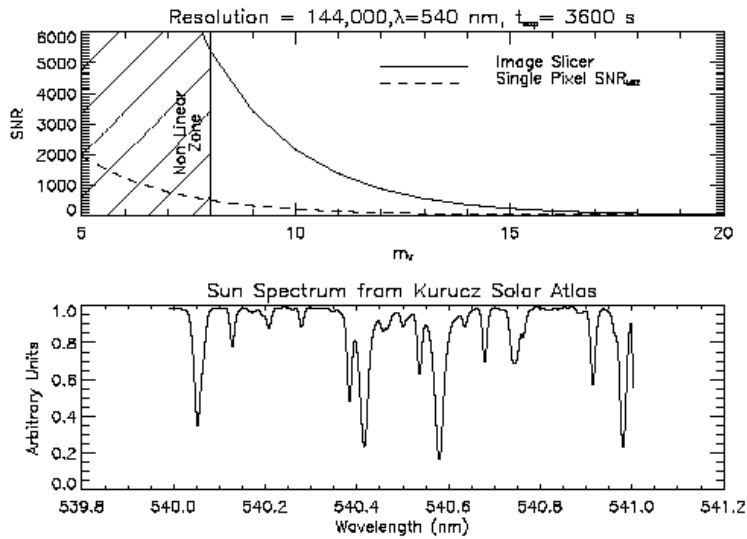


Fig. 5. Expected efficiency of SARG at  $R = 144,000$  (upper panel); and the solar spectrum at this resolution, when coupled with the yellow grism.

SARG uses a single, quite long (500 mm focal length), large field dioptric camera constructed by SESO: the camera uses a design similar to that adopted for the DoLoRes one, reoptimized for our own purposes. The detector is a mosaic of 2 EEV  $2k \times 4k$  CCDs, pixel  $13.5 \mu\text{m}$  (very similar to that in use at the OIG). Measured efficiency of this CCD as a function of wavelength is given in Figure 4

We computed expected performances of SARG in all its configurations. Too much space would be required to show the results of all these simulations; as an example of expected performances of SARG, we give in Figure 5 the expected efficiency as a function of wavelength at the highest resolution ( $R \sim 144,000$ , with the image slicer), when the yellow grism is used (this is the configuration to be used for high precision radial velocities with the iodine cell). In the bottom of this figure, we also show the solar spectrum at this resolution.

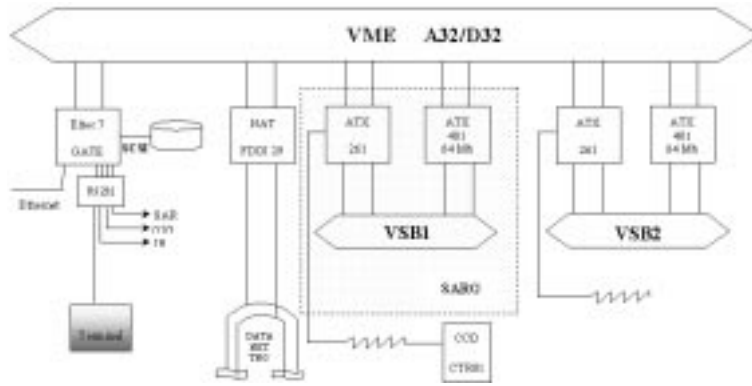


Fig. 6. Layout of the SARG VME control system architecture.

#### 4. Mechanics

SARG mechanics has been constructed by CINEL. It consists of three main components:

- The FM1 unit carries L1 and FM1. It is mounted on the input slide of DoLoRes
- The main spectrograph body includes the slit box (where the preslit optics is mounted), the calibration lamp unit, the slit viewer box, and the mountings for the main optical elements (collimator mirrors, echelle, grisms, camera). All these are located on a Newport optical table. The tables, and all the other elements (save for the calibration lamp and the CCD dewar) are located inside a thick thermally insulating enclosure. There are 9 motorized wheels and tables, that allow remote control of all spectrograph functions. Five of them are realized by means of commercial (OWIS) table; the remaining four are annular rotating tables realized by CINEL
- The Telescope/Spectrograph interface is a steel framework that allow proper handling and positioning of SARG at the arm of the TNG fork (fine alignment is achieved by tip/tilting a thick quartz window located within the optical path)

#### 5. Controls

SARG controls are described in more details in a separate contribution at this meeting; a sketch of its overall architecture is given in Figure 7. It is a VME-system based (see Figure 6); the VME-bus directly controls the Elettromare TNG standard CCD controller by means of a fiber optics link and TNG standard Atenix boards. Instrument functions are controlled by RS232 links to stand-alone controllers (three OWIS motor-controller, a National board commanding the lamps, and a Lakeshore temperature monitor). All these elements are located on a single rack, a couple of meters far from the spectrograph.

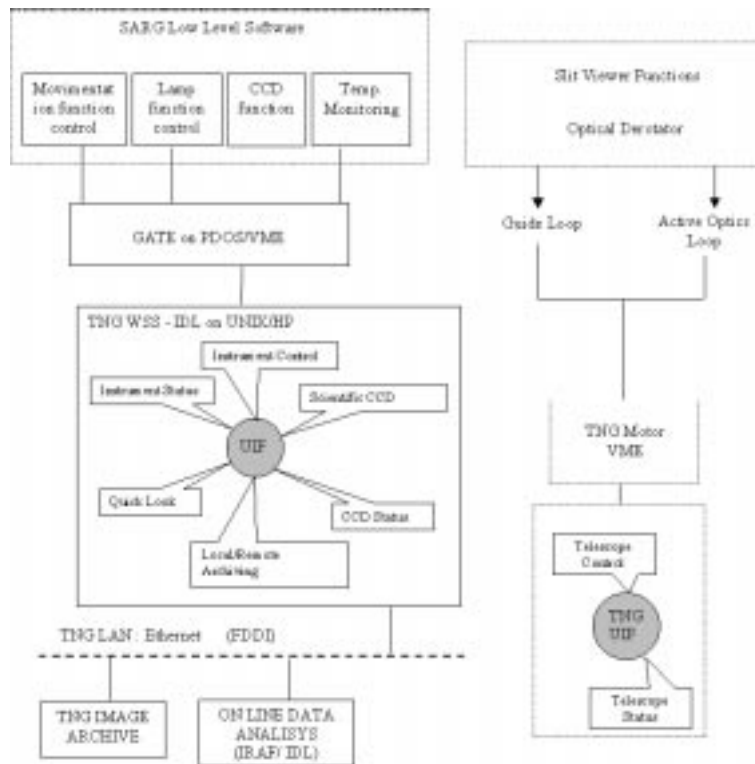


Fig. 7. Layout of SARG control system.

## 6. SARG Distributed Active Thermal Control System (DATCS)

Temperature within the SARG enclosure is kept at  $20 \pm 0.5$  C by means of an active thermal control system. The design of this system was done using a computer model, tested against suitable laboratory experiments. We considered the following environmental conditions:

- Location: during daytime indoors; during night-time, outdoors, partially sheltered
- Temperature range: 0 C to 19 C
- Relative humidity: 45
- Special Conditions: possible transport of dust with wind for surfaces exposed to external environment; forced ventilation
- Max. wind speed: 25 m/s with dome opened for surfaces exposed to external environment. Quiet air in sheltered areas. This last condition applies to SARG

The SARG thermal specifications were set as follows:



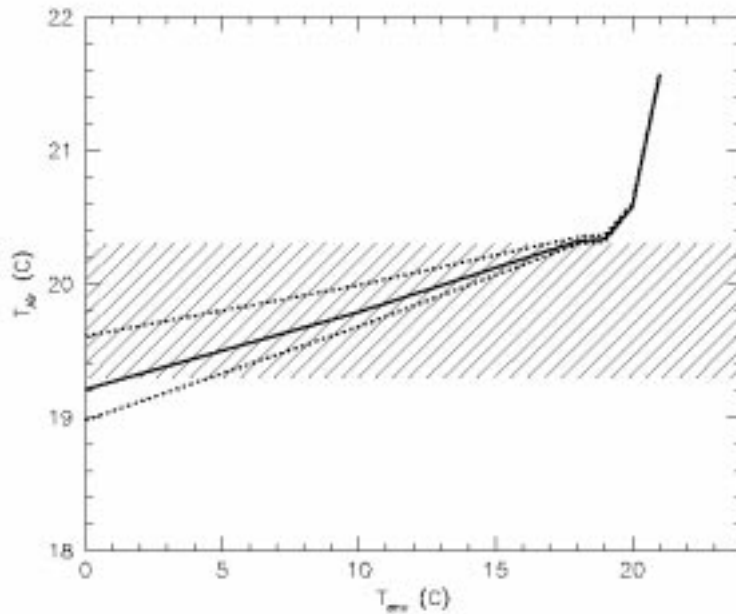


Fig. 8. Run of expected temperature of SARG as a function of temperature in the Nasmyth room when the DATCS is in operation. Solid line represents average (air) temperature; dotted lines are expected minimum and maximum temperatures within the spectrograph. The dashed area represents specifications.

- Long-term stability: (0.5 C
- Thermal inhomogeneities: (1 C
- Rate of temperature changes: (1 C/hr

The spectrograph passive thermal properties are:

- Weight: 750 kg
- Effective Thermal capacity: 534 KJ/C
- Heat Flux through enclosure: 10 W/C
- Thermal Constant: 15 hr
- Total heat losses: 10–200 W (depending on environment temp.)

To achieve specifications, DATCS architecture consists of two main components:

- 30 MINCO CT 198 HEATERSTAT sensorless temperature controllers coupled with thermofoil resistances

- 8 DT-470 silicon diode sensors controlled by a Lakeshore 208 temperature Monitor

Within this design, particular care was devoted to DATCS calibration. To this purpose, a special Heaterstat Calibration Box was constructed, a calibration procedure was defined and strictly enforced, and a maintenance plan was defined in order to maintain conditions stable over a long period of time.

The expected performances of DATCS from our computer model are within specifications (see Figure 8). Strict procedures will be enforced to avoid that during spectrograph heating temperature gradients will not be larger than specifications.