A HIGH RESOLUTION SPECTROGRAPH FOR THE GALILEO NATIONAL TELESCOPE

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ABSTRACT. The design of the high resolution spectrograph (SARG) for TNG is briefly described. SARG will be a fiber-fed, white-pupil echelle spectrograph located in the telescope pillar. In its baseline configuration, it will allow observations at resolution $25,000 < R < 100,000$ in the wavelength range 0.37-0.9 μm, by using two cameras; extension of the wavelength range up to 1.7 μm and of resolution up to 200,000 can be obtained by using two additional cameras.

1. Scientific aims

Instrumentation for spectroscopy is considered to be a part of the basic equipment at every large astronomical telescope. Spectroscopy enables the composition of stars to be analyzed, the masses of galaxies and intergalactic clouds to be measured, and the state of gaseous nebulae to be determined - all on the basis of their spectra.

Most spectrographs aim at a spectral precision (*resolving power*) of 30,000 to 50,000. Most modern designs call for the use of diffraction gratings to achieve this, and frequently gratings of the *echelle* type are chosen. An echelle grating calls for a complex, but well-understood, optical design.

The High Resolution Spectrograph for the Galileo Telescope (SARG) is unusual in having a resolving power from 25,000 to 100,000 and almost unique in proposing an extension to 200,000. Even more importantly, SARG is being optimised for astronomical studies which require high thermal and mechanical stability. This will allow scientific programs to be carried out which are not possible at general-purpose observatories. One of these programs is *astroseismology*, which is the study of stellar structure by observation of vibrational modes of the star as a whole. This *ringing* of the star gives rise to minute changes in the spectrum which is only measurable by an instrument of high resolving power and stability, such as SARG, and only after a long period of continuous measurement. Solar-type stars will be monitored for several weeks, hopefully allowing the characteristic 9 μHz frequency difference between p modes to be detected down to magnitude 4 or 5.

Other scientifically driving programs include the search for planets around stars other than our own Sun, which is, arguably, one of the most important endeavours in a social sense. The existence of such planets is widely believed but has never been confirmed and may profoundly affect the phylosophical basis of our culture. The effect of a positive result in the subsequent search for signs of life emanating from the planet would of course be incalculable. With SARG we will be able to reach magnitude 11 for this work and thus, in principle, to monitor several hundred thousand stars. SARG has a multiple-object facility so that in many cases up to 10 stars can be observed at once. Up to now only a couple of stars have been observed: in a single year of dedicated operation SARG will observe several thousand and thus establish the scientific base for the entire field.

On a very different topic, SARG may also significantly contribute to our understanding of QSO absorption-line systems: this is normally in the realm of costly large-telescope science. SARG will enable programs spanning several months, such as a systematic study of absorption lines at different redshifts. SARG is also equipped with an infrared camera so that interesting systems can be imaged (normally this would require two instruments and a six-month delay).

2. Instrument description

The High Resolution Spectrograph (SARG) ($25,000 \leq R \leq 100,000$), will be placed in the pillar of the Galileo National Telescope (TNG), presently under construction at Roque de los Muchachos (La Palma, Canary Island, Spain). SARG has been designed in order to perform highly competitive observations concerning asteroseismology, search of planets and brown dwarfs around nearby stars, studies of the solar system, of stellar atmospheres, of the interstellar medium, of the chemical evolution of our Galaxy, and of absorption lines in QSO's spectra.

SARG is a fiber-fed, single-arm white-pupil echelle spectrograph with multiple cameras. Although fiber feeding efficiency is not larger than 60% of direct feeding one, this solution was adopted due to its higher stability, versatility, and compatibility with other TNG instruments, allowing SARG to be permanently on-line. This configuration also allows to share with the Low Dispersion Spectrograph (LDS) a number of functions, including acquisition and pointing software, ADC corrector, and integrating sphere for comparison lamps.

The fiber head will share the Nasmyth platform with the LDS: the focal plane can be alternatively occupied by the multislit holder of the LDS, or by the fiber probe holder of SARG. A 90 degree rotation of a lever arm will move the fiber probe platform from the in-focus position to the fiber positioner and *viz.* Within the fiber holder, each fiber is connected to a fiber probe, which position is computed on the basis of images taken with the LDS in focal reducer mode. The fiber probe is a small cylinder with a 45 degree reflection prism inside. The input end of the fiber is plugged laterally to the vertical surface of the prism through an appropriate connector. The fiber will be protected by a small hard-material cylinder, to minimize the bending effects during the positioning process. The fiber positioner (allowing simultaneous use of up to 10 fibers over a choice of 30, for observations over a field of 10 arcmin) will exploit the same technological solutions adopted for the LDS siltlet array.

The fiber-spectrograph interface is guaranteed by an f/4.5 to f/10 preslit transfer optics with three interchangeable subunits (UV-blue, visible and IR), selectable by translating a small 45 degree. This preslit optics has an afocal design allowing the change in the input focal ratio, the correct formation of the pupil image on the echelle grating, and low straylight level, as provided by two field and one aperture stops.

The collimator is a three-mirror system, composed of two off-axis paraboloids (collimator and transfer collimator) and of a flat (folding mirror). The collimated beam has a diameter of 200 mm; the off-axis angle of the collimator is 5.6 degrees; the useful field at slit is 7 mm. The echelle is an 204×408 mm R2 with 31.6 gr/mm; it is used in quasi-Littrow configuration, with an off-plane angle of 0.6 degrees. Four grating cross-dispersers (optimized for either single- or multi-object observations over the whole visible range) can be moved into the optical path by rotating a grating platform; each cross-disperser is mounted on a rotating turret for wavelength range selection.

Baseline design includes two cameras: a short (f/2.15) dioptric camera to be used for observations at $R = 25,000$ and $R = 50,000$; and a long (f/4.8) camera to be used for observations at $R = 100,000$, in conjunction with a Bowen-Walraven image slicer; both dioptric and folded-Schmidt designs are considered for this camera. Each camera will be provided with a thin, back-illuminated large format CCD detector. Specialized coatings will be used, yielding a high overall efficiency (about 0.10 at peak).

Two additional cameras are included in SARG design, though they are not presently considered in the instrument baseline: a very long camera (either of an off-axis three-mirror or of a Maksutov-Cassegrain design) for observations at extremely high resolution (R=200,000), to be used together with a special Bowen-Walraven image slicer, and special wedges for wavelength range selection within the echelle free spectral range; and a cryogenic IR camera, extending the spectral coverage up to 1.7 μm at a resolution of R=50,000. This IR camera may be fed by inserting a folding flat in front of the cross disperser; wavelength selection within the free spectral range is performed by a second, rotating folding flat. Thermal background suppression and order selection is allowed by a cooled grism; in this preliminary design, a NICMOS3 detector is considered. If realized, the very-long camera will be very useful for investigations of stellar atmospheres and of the interstellar medium, while the IR camera should provide basic data for studies of circumstellar regions and of the clouds responsible of QSO absorption lines.

Overall cost of SARG according to the baseline design (excluding Very Long and IR cameras and detectors) is 1.5 million US dollars; commissioning is scheduled for second half, 1997.