LIRIS (Long-slit Intermediate Resolution Infrared Spectrograph) Project status

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ABSTRACT

LIRIS is a near-infrared (0.9-2.4 microns) intermediate resolution spectrograph (R=1000-8000) with added capabilities for multi-object, imaging, coronography, and polarimetry. This instrument is now being constructed at the IAC, and upon complexion will be installed on the 4.2m William Herschel Telescope (WHT) at the Observatorio del Roque de Los Muchachos (ORM, La Palma). The optical system uses lenses and is based on a classical collimator/camera design. Grisms are used as the dispersion elements. The plate scale (0.25 arsec/pixels) matches the median seeing (0.5 arcsec in the K band) at the ORM. The detector is a Hawaii 1024x1024 HgCdTe array operating at 60 K.

Keywords: Near-IR, Imager, Spectrometers, Multi-object.

1. INTRODUCTION

The advancement of Infrared technology over the past few years, especially in the fields of detectors and cryogenics, has allowed the development of IR spectrographs with similar characteristics to optical ones. This opens a new window to astrophysical research. With this idea in mind, we started the design of LIRIS in 1998[1]. LIRIS is conceived as a common user instrument for the WHT at the Observatorio del Roque de los Muchachos (ORM La Palma) to fill a gap in the current instrumentation at the ORM. The main philosophy of LIRIS is: to maximize of the scientific versatility/technical complexity ratio; to keep overall costs within reasonable limits, and to have the instrument on the telescope within about 3 years.

LIRIS is a near-IR spectrograph working the range between 0.9 and 2.4 microns with image capability, which allows easy target acquisition. Design was based on lenses and grisms to make the design more compact. Besides having operation modes similar to other IR spectrographs, LIRIS adds some unique modes such as: coronography, multi-object spectrograph, and polarimetry.

The main LIRIS features are listed in Table 1 and an schematic representation of the instrument is presented in Figure 1.

2. SCIENTIFIC CASE

Given its common-user status, it should be possible to use LIRIS for a wide range of astrophysical disciplines, including the areas of stellar, planetary, extragalactic and cosmological physics. We list below some of the most relevant possible scientific applications (a more detailed description has already been presented[1]):

- Spectroscopy of proto-planetary nebulae
- Detection of very low mass secondaries, planets and brown dwarfs.
- Spectroscopy of nearby and distant galaxies with massive star formation: nearby HII regions and distant starbursts.
- Stellar kinematics and populations in spiral galaxies.
- Physical conditions of the gas, and the stellar kinematics and populations of starburst galaxies and AGNs.

- Ultraluminous infrared galaxies.
- The fundamental plane of high-redshift elliptical and S0 galaxies.
- Redshift measurements of infrared sources.

Focal Station	Cassegrain
Wavelength range	0.9 - 2.4 µm
Array format	Rockwell Hawaii 1024x1024 HgCdTe
Scales at detector	0.25 arcsec / pixel
Observing modes	Imaging ,Long-slit Spectroscopy, Multi-object spectroscopy, coronography with apodization masking and Polarimetry
Detector working temperature	60 K
Imaging mode	
FOV	4.2 x 4.2 arcmin
Sensitivity	K=22.13, H=23.68, J=24.75, Z=25.24 for t=1hr, S/N=3 in 0.5 arcsec seeing.
Spectroscopy mode	
Slit Length	4.2 arcmin
Slit Widths	0.5", 0.75", 1", 2.5" and 5"
Spectral resolution	Low / medium resolution: R=1000 / 3000 for slit width 0.5" (4 grisms) High resolution: R= 8000 for slit width 0.5" (2 grisms)
Spectral coverage	From 0.887 to 1.531 µm [bands Z and J, R=1000] From 1.388 to 2.419 µm [bands H and K, R=1000] From 0.997 to 1.185 µm [bands Z , R=3000] From 1.178 to 1.403 µm [bands J , R=3000] From 1.451 to 1.733 µm [bands H , R=3000] From 2.005 to 2.371 µm [bands K , R=3000] From 2.079 to 2.147 µm [bands K , R=8000] From 2.267 to 2.420 µm [bands K , R=8000]
Sensitivity	R=1000: K=18.79, H=20.27, J=21.50, Z=22.26 (continuum) R=3000: K=17.91, H=19.37, J=20.53, Z=21.19 (continuum) In both cases for t=1hr, S/N=3, FWHM=0.5" .
Multi-object Spectroscopy mode	
Number of masks	10 multislit masks available.

Table 1.- Instrument features.

3. OPTICS

LIRIS is based on a classical collimator/camera design. The light passes through a Fused Silica window and forms the telescope focus on a cold aperture mask. A BaF2 - Fused Silica - BaF2 triplet collimates the input light and forms an image of the primary mirror at the cold stop. This collimated beam passes through the pupil optics: filters, grisms, apodization masks and Wollaston prisms which are mounted on wheels for easy change in operation modes. The camera uses a Petzval concept with 4 lenses: BaF2 - Schott SF6 doublet, BaF2 singlet and a BaF2 field lens.

The detector will be mounted in a cold translation mechanism to compensate for non-achromaticity along the observing spectral range. Total translation range will be ±2.5 mm along the optical axis.

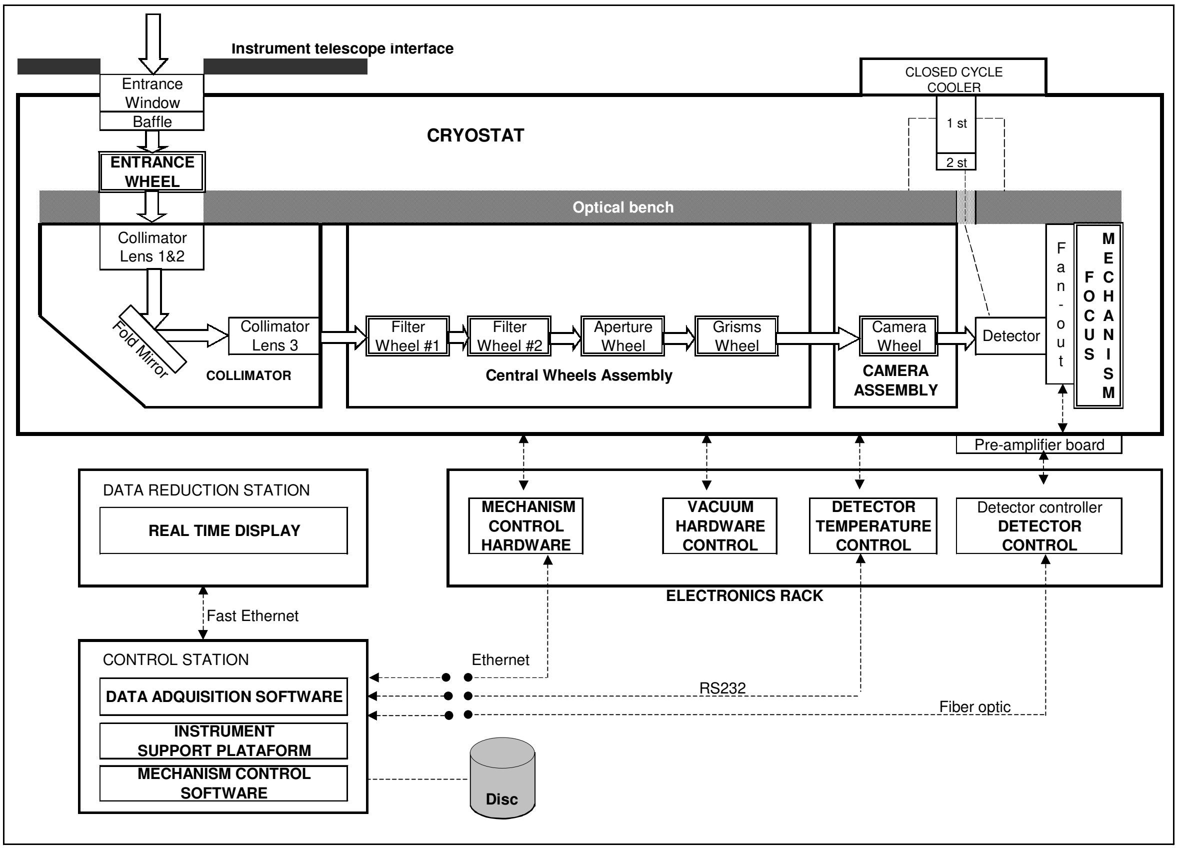

Figure 1.- LIRIS schematic representation.

3.1 IMAGE QUALITY

The image quality is such that the 80% of the energy of the Point Spread Function (PSF) is encircled in a diameter less than 25 µm for all bands (equivalent to 0.34 arcsec at the detector scale).

3.2 GRISMS

Here the set of grisms already ordered is listed. Low resolution grism are replica grism, while high resolution ones are directly ruled. The use of high refractive index subtract (Germanium) allow us to achieve resolution as high as 8000.

Material	λ_ini	λ_cen	λ_end	Order	Resolution
Corning_9754	0.887	1.209	1.531	1	960
Corning 9754	1.388	1.904	2.419	1	945
KRS5	0.997	1.091	1.185	6	3000
KRS5	1.178	1.290	1.403	5	2900
KRS5	1.451	1.592	1.733	4	2900
Germanium	2.005	2.188	2.371	1	3000
Germanium	2.0796	2.1468	2.2140	1	8100
Germanium	2.2668	2.3436	2.4204	1	7800

Table 1.- LIRIS Grisms

3.3 FILTERS

A set of broad and narrow band filters will be provided. All filters have been acquired via a consortium lead by Dr. A. Tokunaga. In Table 2 the filters are listed.

Filter Name	Cut-on (in microns)	Cut-off (in microns)
Z	0.996	1.069
J	1.170	1.330
H	1.490	1.780
K_s	1.990	2.310
Br-gamma	2.150	2.182
K-continuum	2.253	2.287
H-continuum	1.558	1.582
[FeII]	1.632	1.656
H2 v=1-0	2.106	2.138
H2 v=2-1	2.231	2.265
CH4_l	1.640	1.740
He I	2.043	2.073

Table 2.- LIRIS filters.

3.4 THROUGHPUT

The optics of LIRIS are all refractive, with the exception of a single folding flat mirror in the collimator assembly. The expected throughput (averaged across the wavelength range) for the optics is 80% and 64% in imaging and spectroscopic modes, respectively. The grism transmission is assumed to be 80%. The total throughput including the optics, filter and detector is 35 % and 30% in imaging and spectroscopic modes, respectively.

4. MECHANICS

The optical layout and the functional specification have driven the design of the instrument. The great versatility combined with the high image quality have significantly shaped the instrument layout.

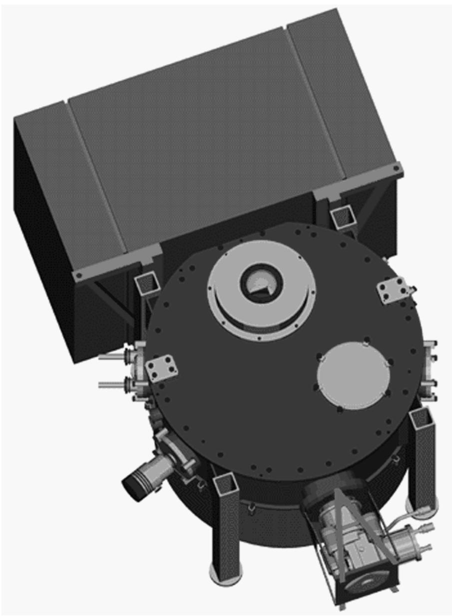

Figure 2.- LIRIS external view (© UKATC).

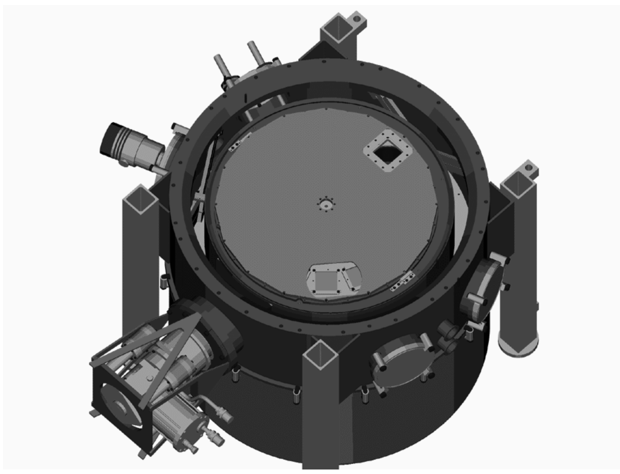

Figure 3.- LIRIS with front cover and radiation shield removed (© UKATC).

The large entrance wheel sets the shape of the cryostat and its internal hardware, with the optical axis close to one edge. The whole cryostat is offset with respect to the optical axis of the telescope. It is counter-balanced by its electronics rack, which will form an integral part of the assembly.

4.1 CRYOSTAT

The vacuum vessel is a welded cylindrical vessel. It is made in three sections, a central ring and two end covers. The front cover is a circular plate which carries the window and its mounting and a cover over the port giving access to the entrance wheel. It is not necessary to remove the front cover to change focal plane masks. The rear cover could be removed to gain access to all the other internal modules of the instrument. It has an auxiliary access port to facilitate the first integration &alignment steps without detector.

The center section carries all the semi-permanent access ports. These carry ports for electrical wiring, cooling and vacuum pumping.

A Finite Elements Analysis is being made in order to finalize the design and to choose the material for the vacuum vessel, as well as the design of the trusses and the optical bench. Figure 4 shows some of the results for the optical bench.

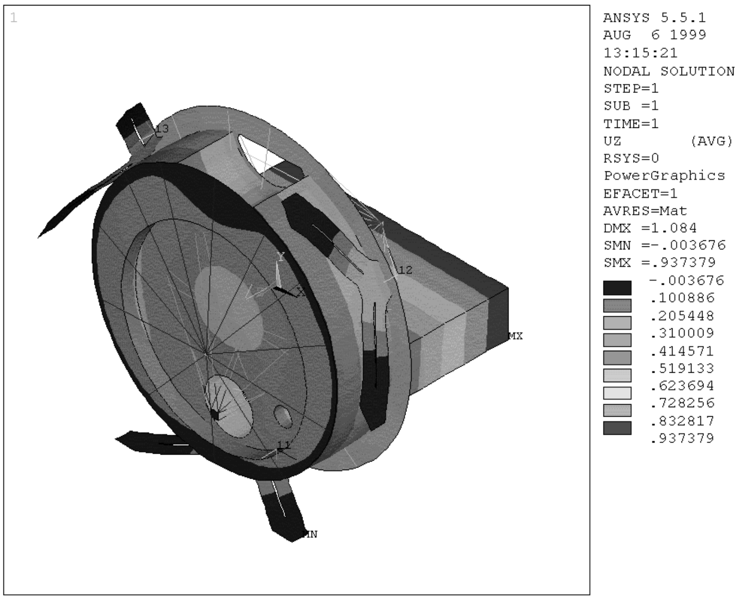

Figure 4.- Optical bench's displacement for thermal and pressure loads.

4.2 COOLING SYSTEM

The cold mass of the instrument is about 200 Kg and is pre-cooled with LN_2 held within the structure of the optical bench. The cooling system is a two-stage CTI model 1050C closed-cycle refrigerator. This works on the Gifford-McMahon cycle and has typical cooling powers of 45W @ 60K plus 4W@ 15K. The first stage cools all the cold parts of the instrument, except for the detector and its housing. The closed-cycle cooler is mounted in an anti-vibration mounting and joined to the optical bench by flexible thermal links.

4.3 RADIATION SHIELDS

Together with the optical bench, there are two radiation shields that form a light-tight cold enclosure for the instrument as well as photon traps. The radiation loads on the instrument are reduced by multi-layer insulation (MLI) formed into three sections of blankets. The front radiation shield has two functions: to support the front MLI blanket and to carry and cool the stray-light rejection baffle. It has an access port so that masks in the entrance wheel can be changed from outside with the minimum of disturbance. The rear radiation shields serves to conduct the heat, which passes through the MLI blanket away to the optical bench.

4.4 OPTICAL BENCH

The bench is an aluminium welded structure, supported from the front ring of the central section of the vacuum vessel by three trusses made from G10 glass-epoxy composite. It has a cylindrical shape and its plates acts as a reference surfaces and mounting for all the cold modules. The bench will be also used as a tank for LN_2 for pre-cooling the instrument. The front plate supports the entrance wheel. The rear plate supports the rest of the cold parts. The optical bench is fitted with a panel heater to allow a controlled warm-up while still under vacuum.

4.5 MECHANISMS

There are four mechanism modules: the entrance wheel, the central wheels, the camera wheel and the focus mechanism. The entrance wheel carries 15 masks plus an aperture, each with a clear aperture of 57 mm square. The central wheel module contains the four wheels carrying optical elements: two filter wheels, with 12 holders each, an aperture wheel and the grisms wheel, which carries 9 grisms plus an aperture. The camera wheel contains the main camera and the re-imagination pupil camera. The focus mechanism contains the detector and its housing.

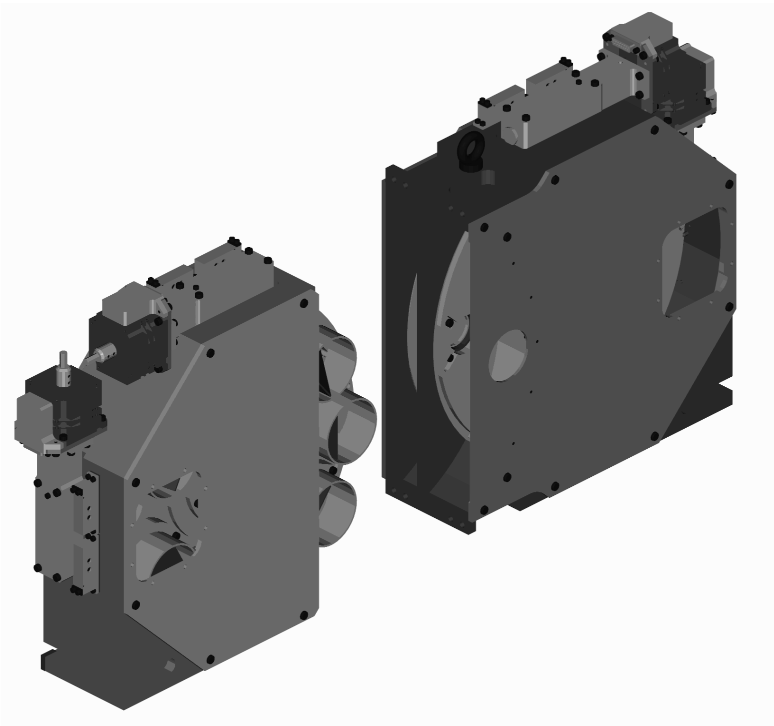

Figure 5.- Central Wheels sub-assemblies (© UKATC).

These six wheels are worm wheels driven by stepping motors mounted on the outside of the module housing. The drive unit assembly is common to all the wheels. It is based on stepping motors with double-ended rotor shaft and with 500 steps per revolution. The worm is made from DuPont Vespel SP3, which makes it a self-lubricating in cryogenic conditions. It is carried on a stainless steel shaft. The aluminium wheels have teeth cut as a helical gear, in order to remove one constraint on the assembly tolerances. A central hub with two back to back angular contact bearings that provide high tilt stiffness supports all wheels. Such bearing arrangement also provides a satisfactory thermal path to allow cooling of the wheels. A cam-operated microswitch determines the datum position.

The focus mechanism is based on Jones´ classic parallel motion flexure design adapted for cryogenic use. The mechanism consists basically in a focus stage and a drive unit. The focus movement is produced by a leadscrew and nut driven by a stepping motor through a train of three gears. It gives a total travel of 5,6 mm.

5. DETECTOR AND MECHANISM CONTROLLERS

5.1 DETECTOR CONTROLLERS

The controller system for the 1024x1024 IR Hawaii detector by Rockwell[1] uses the SDSU controller[3], a commercial product developed by the San Diego State University, and is supplied by IRLabs (Tucson, AZ). It is based on the 56200 DSP by Motorola and although initially intended for CCDs, it is also suitable for controlling IR detectors.

A modified code developed by P. Moore[4] of the Isaac Newton Group (ING[5]) for the Ingrid Project[6] is being used. This code will be expanded, in a future version, to include reading modes such as ramps and windowing of the detector. To cope with this, a new fanout board to allocate the detector was developed at the ING. All the Clocks and Bias pins of the four detector independent quadrants are accessible from the edge connectors of the fan-out board, thus allowing the partial reading of arbitrary portions of the detector. In the present version the four quadrants of the detector are driven at the same time with a reading rate of 3 μsecs/pixel, leading to a time of 0.9 seconds for a complete frame readout.

The SDSU controller communicates with the control computer through two optical fibers, receiving elementary commands at 4 MHz and transmitting status and/or data at 50MHz. The optical fibers link the master board at the SDSU controller with an I/O board, with a small buffering capability, plugged at the SBUS of the computer (SUN workstation).

Due to the thermal dependence of the signal offset level of the detector, a temperature controller is required to achieve a spec. of a rms noise of less than 0.01e-. According to the experience of the Ingrid team[7] and others (G. Finger, ESO, 1999, private communication) the required stability must be better than 0.005K. The selected controller is the Lakeshore 340 and the sensors are Cernox RTDs by the same manufacturer. This controller is also in charge of maintaining a positive gradient between the detector and the cold finger for safety during the warm up cycles. It communicates through optical fibers with the control computer using a standard RS232 protocol.

Initially Double Correlate (CD) and Multiple Non Destructive Reads (MNDR) are the only read out modes. Figure 6 shows that a number of eight reads in the MNDR mode will be enough to be background limited in the most demanding conditions.

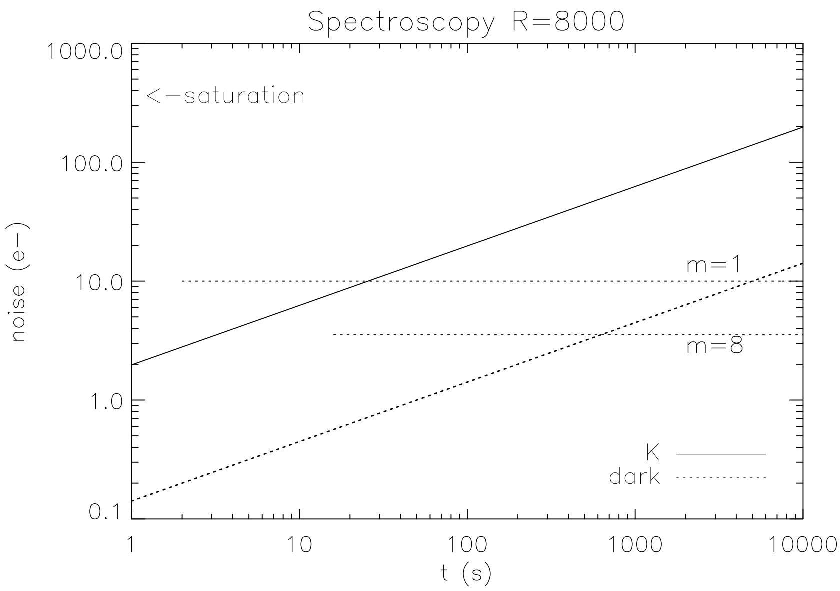

Figure 6.- Different sources of noise due to dark current, read out and background

5.2 SENSITIVITY

Sensitivity curves have been worked out including the atmospheric transmission and reflectivity of the WHT telescope.

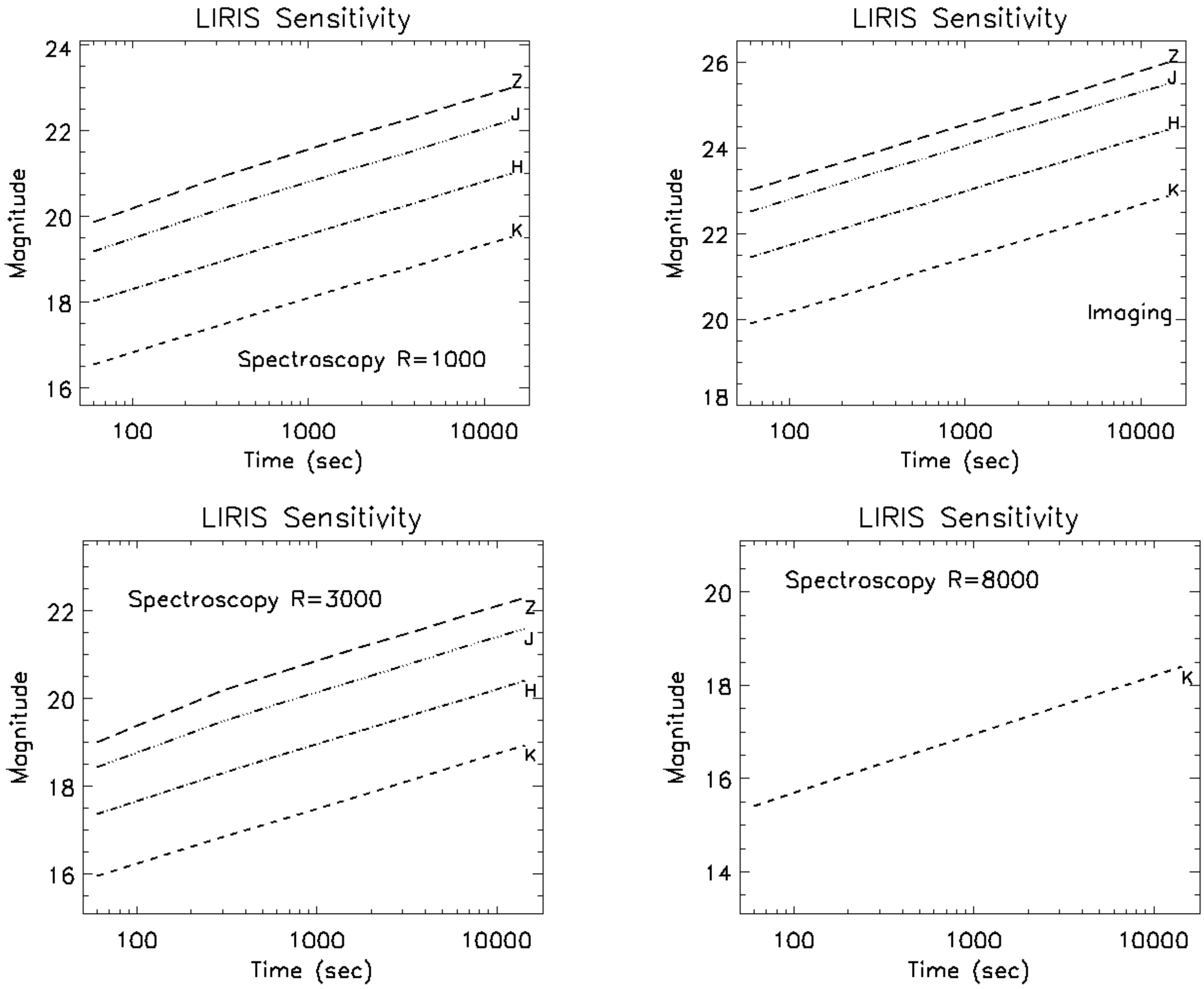

Figure 7.- Sensitivity curves for different bands and different observing modes

5.3 MECHANISM CONTROLLER

The mechanisms control system is based on a VME system with a Motorola CPU card running VxWorks operating system and two Oregon Micro Systems stepper motor controller boards, allowing a total number of twelve motors to be controlled, each one of them with its own home, limits and power off signals. The VME rack is 19" wide, 3U high, with five double height slots. All signals are available on the backpanel. The VME system is connected to the SUN through an Ethernet network and an RS232 line. An additional 19" 3U rack with the motor drivers will be installed under the VME rack. The drivers will be purchased from the same manufacturer as the motors'.

6. SOFTWARE DESCRIPTION

The LIRIS Software system is being designed to be fully integrated in the observer environment available at the WHT. A common observer will have access to the following software packages (see Figure 8):

Instrument Simulator Software: Given the source characteristics (expected brightness, extended or point source, sky brightness) and an observing mode (imaging or spectroscopy, dithering or beam switching), a LIRIS simulator will be used to obtain the S/N ratio for a given integration time or viceversa. It will also provide the instrument configuration suitable to carry out the desired observation, i.e. it will be able to generate the templates which can be interpreted by the Template Generator Software (described below). It will also have access to whole sky standard catalogues (POSS, 2MASS, IRSKY) in order to simulate what is included within the LIRIS aperture (it is especially important for background positions and spectroscopic observations). This component may be accessed by general observers at any place, as an HTML application.

Templates Generator Software: This package will be used to define the LIRIS observing parameters. It will have a set of predefined modes, called ***templates***, adequate for the most common types of LIRIS observations. Each of them will have a number of configurable parameters (exposure time, detector reading mode, filter selection, etc). This system will generate a sequence of commands or scripts which can be interpreted any of the systems available at the Instrument Support Platform.

Instrument Support Platform User Interface: This package will be the main observer GUI for LIRIS. It will provide the support infrastructure required to operate the instrument,. including facilities to set up exposure parameters, data acquisition from the instrument detector, pointing the telescope, and also the execution of LIRIS Observing Templates.

LIRIS Mechanism Control Software: This system can receive commands from the Instrument Support Platform and return status information. It comprises the following 2 subsystems:

LIRIS EPICS Mechanism Control Software: This system is the responsible of the direct control of the LIRIS mechanisms (filter, slit, and grism wheels and detector focus). This software will run on the VME EPICS rack.

Temperature Controller Software: This system will be used to control and monitor the detector temperature. ..

Real Time Display: This tool will be use to monitor the newly acquired images. It will basically process and display them using Ximtool / SAOtng as display device. These tools offer facilities to change color tables, zoom, several image frames. It will also provide some facilities: basic statistics, different scaling of the representation, and additionally there will be a seeing and background monitor.

Quick Look Data Analysis: This package will provide facilities for a quick analysis of the recently acquired data. This should include facilities to perform sky subtraction, coaddition and alignment of images, extraction of spectra, default wavelength calibration. It will be based on existing astronomical data analysis packages, like IRAF.

Pipeline Data Reduction: This package will be used to process blocks of images obtained through the LIRIS Observing Templates. It will receive notifications of available data blocks from the Instrument Support Platform in order to start the processing. The following steps will be done: detector effects removal, flat-fielding, sky subtraction, coaddition and alignment of images. For spectroscopy there will be a default wavelength calibration.

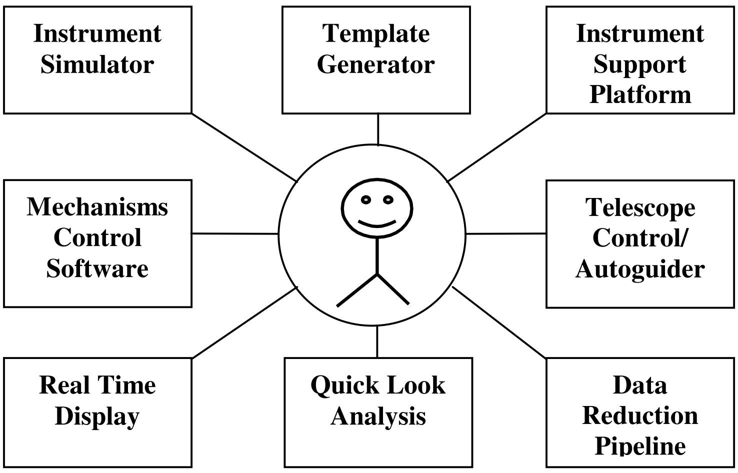

Figure 8.-LIRIS Observing Environment

7. CURRENT STATUS

The detailed optical design is finished (under contract by UKATC). The fabrication of the optics is under way (by JANOS Technology[8]). Delivery of the camera in March 2000 is expected. The filters, grisms, wollastons and wave retarders have already been contracted, the expected delivery will be during year 2000. An purpose-built optomechanics test bench has been designed.

The conceptual mechanical design is finished (under contract by UKATC). The detailed mechanical design is under way at the IAC and expected to be finish by May 2000. The fabrication of mechanical parts has already started. An purpose-built entrance wheel test bench has been designed and manufactured.

Two options for the stepping motors are being considered: the Bergher-Lahr 5-phase modified for cryogenic use, or the Phytron 4 phase cryogenic motors. Currently both motors are being tested. The final decision will be taken depending on their performance

The engineering grade detector has already arrived, and the science degree array is expected by summer 2000. An purpose-built detector test bench has been designed and manufactured. In collaboration with the INGRID Project Team of the Isaac Newton Group (ING) a first version of the Data Acquisition Software (DAS) and the Real Time Display (RTD) have been developed.

The Assembly, Integration and Verification plan is under development and we will start assembling by summer 2000. We expect to have first light and commissioning at the telescope in summer 2001.

For on-line information about the LIRIS project our web site is http://www.iac.es/proyect/LIRIS/.

8. ACKNOWLEDGEMENTS

An agreement has been established between the Instituto de Astrofísica de Canarias (IAC) and the Isaac Newton Group (ING) to develop a common system for the two infrared instruments (LIRIS/IAC and INGRID/ING) that will be sharing the Cassegrain focus of the WHT. Both instruments will interface to the common user instrumentation control system of the telescope. We specially thank the INGRID Project Team for their help. We thank D. Ives, T. Purkins and S. Ramsay (UK-ATC), G. Finger (ESO), and P. Bizenberger (MPIA) for their stimulating discussion and valuable advice. We thank P. Cobos (UNAM), R. Lenzer (MPIA), U. Käufl (ESO), K. Dee (ING), T. Gregory (NOT), E. Cadavid (IAC) and L. Cavaller (GTC) for their participation as external reviewers.

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