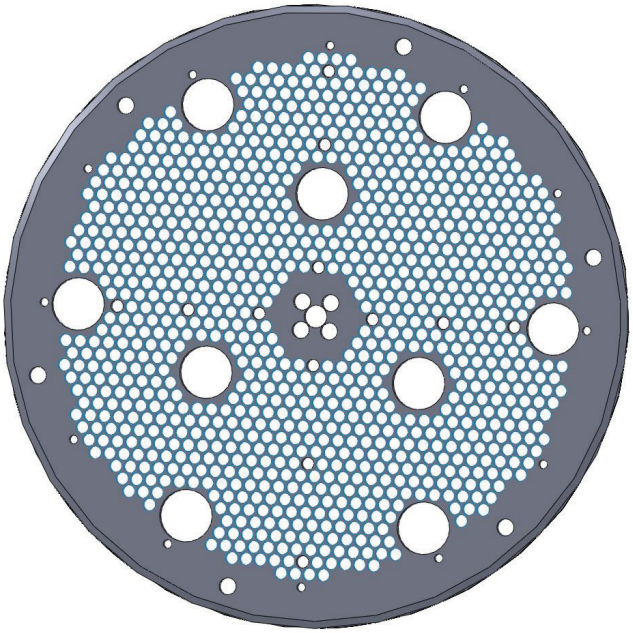
Conceptual Design Study

for the

GTC Optical Intermediate Resolution Spectrograph

(GO-IRS)

Volume I
Introduction and Science Cases



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3. Executive Summary

The University of Florida (UF) submits this conceptual design study on an optical intermediate resolution spectrograph for the GTC in fulfillment of its obligations under the GTC contract. With this study, the UF-led team proposes to design, construct, integrate, test, and deliver to GTC, the GTC Optical Intermediate Resolution Spectrograph (GO-IRS). The UF-led team with a major partner, the University of Science and Technology of China (USTC), is uniquely qualified to deliver GO-IRS by virtue of its extensive combined experience in the construction of state-of-the-art astronomical optical spectrographs and advanced multi-object fiber positioners, and its commitment to excellence in support of the GTC. The team has the experienced scientific, engineering, and management personnel, and the facilities to study, design, construct, integrate, and test a facility instrument of the highest quality for GTC. Scientifically, the team has the expertise to utilize guaranteed time to conduct major, ground-breaking astronomical surveys once the instrument is commissioned, and envisioned as fully open to participation by the full GTC community.

Dr. Jian Ge of UF will lead the GO-IRS project as Principal Investigator by directing the overall GO-IRS effort. Dr. Jose Caballero will serve as Project Scientist. Drs. Anthony Gonzalez and Tinggui Wang of UF will serve as Deputy Project Scientists. They will lead the entire science team in the study of science cases and provide overall science drivers and requirements for the instrument development. Subsequently, they will conduct the initial science surveys once the instrument is commissioned at GTC. Dr. Yipeng Jing of Shanghai Astronomical Observatory (SHAO) serves as co-Principal Investigator in China, responsible for the overall technical and science efforts in China while Dr. Jiaru Chu serves as Technical Leader in China, leading the fiber positioner development in USTC. Scott Powell serves as Project Manager to provide overall management control for hardware development and Jian Liu serves as the coordinator over all international affairs.

The technical requirements from GTC in the Announcement of Opportunity have been carefully reviewed while working closely with the international science team to define science cases and requirements. Through an intensive and detailed systems engineering process, a new multi-object optical intermediate resolution spectrograph concept has been developed to meet the GTC technical requirements while providing three major astronomical science areas in the coming decade for GTC. Three possible surveys addressing these areas are described below:

- “Near-field cosmology” in the Milky Way to observe approximately 200,000 MW stars with R=20K (the 2E5 survey)
- Nearby galaxies: resolved stellar populations and kinematics with R=10K
- The GTC GO-IRS Galaxy Deep Survey (3GDS) to observe ~200,000 galaxies at z~0.5-1.6 with R=2-5K

The proposed instrument has the following capabilities: multi-object fiber-fed spectroscopy of 1000 objects simultaneously at R=5K, 10K, and 20K over a field of view of 15 arcmins, and an integral field unit mode with four 20 x 20 fiber bundles (8 x 9 arcsec per bundle on sky and a total of 1600 fibers) at R ~ 7K, 13K, and 20K over the central 2 arcmins of field of view. Both of these observing modes operate over the entire optical wavelength range (3700-10000Å). Two identical spectrographs will be built to cover 1000 MOS or 1600 IFU or 500 MOS plus 800 IFU for versatile science observations. Each spectrograph has a blue channel with a 4k x 4k Fairchild

CCD camera and a red channel with a 4k x 4k LBL red sensitive CCD to provide flexibility in covering any part of blue and red spectra.

The GO-IRS concept may well be the most ambitious ground-based optical multi-object spectrograph for 8-10 meter telescopes. This ambitious concept only becomes practical because of the successful development of the even more highly multiplexed 4000 object LAMOST fiber positioner developed by the USTC, the other major participant in this proposal. Full advantage is taken of this cutting edge technology and the USTC's team experience to design an improved, but less multiplexed, 1000 object capability fiber positioner by populating the entire GTC 15 arcmin field of view at the folded Cassegrain focus with 1000 high precision fiber robot units and the central region with four fiber bundle robots. High throughput is ensured by optimizing fiber feeding, spectrograph transmission, and choosing very sensitive CCD's in both channels. GO-IRS, once built, will address the strong desire from the GTC community to provide powerful cutting-edge scientific capabilities in the competitive world of large telescope instrumentation.

It is estimated that 124,212 hours (including 70366 hours at USTC for developing the fiber positioner) will be required to design, construct, integrate, test, and deliver the GO-IRS. This is the minimum labor effort reasonable to complete this ambitious and powerful instrument. Based on this labor estimate and the considerable capital expenses, the total budget for the GO-IRS project, excluding approximately $3M as the Chinese contribution (see the commitment letter from China), is $7,552,439, including an explicit contingency of $1,484,504, an allowance of 30% on direct costs. This budget slightly exceeds the cost target in the Announcement of Opportunity, but this budget is considered necessary to deliver the full suite of complex and powerful capabilities required for this instrument, based upon our considerable experience with optical instruments and our careful study of the GO-IRS requirements. The team has considered several descope options and came up with a plan to develop one single channel spectrograph capable of observing half of the original object capability (i.e., 500 MOS or two IFUs with 800 fibers, or 250 MOS + one IFU with a 20x20 lenslet array) for a total cost of $4,909,218. This option would still provide the GTC community a very powerful optical multi-object spectrograph for a broad range of cutting-edge research.

The instrument is proposed for delivery to GTC on Aug. 27, 2013 and will complete commissioning onDecember 6, 2013. This schedule is quite realistic based upon the team's past experience in building similar scale optical instruments. Our team is fully committed to providing the resources needed to complete this instrument on schedule, and is ready to begin work on the project as soon as GTC completes its review of this study and selects this concept for implementation.

The GO-IRS the instrument, when online in the fall of 2013, will have unique capabilities that are extremely valuable to the community in the age of other new facilities such as the James Webb Space Telescope (JWST) and the GAIA mission. GO-IRS is intended to have 1000 fibers that can be used at R=2000-20000 and a wavelength range of .37 - 1μm, capabilities that together make it a uniquely powerful survey instrument.

At a fundamental level, the next generation of GTC instruments must be ambitious in scope, unique in their capability, and capable of addressing some of the most pressing questions in

astrophysics. If the scientific vision of the ASTRONET consortium is considered for a sense of perspective, GO-IRS will have the capability to probe answers for three of the four main questions listed in that vision, and many sub-questions:

Do we understand the extremes of the universe? (Design Reference Case 3)
How do galaxies form and evolve? (Design Reference Cases 1,2,3)
How do stars and planets form? (Design Reference Case 1)

To have a significant scientific impact, it is important that GO-IRS has both the flexibility and capability to enable research that is in the forefront of both galactic and extragalactic astronomy. Three key science cases were considered in guiding the design of this instrument, which are described in the following subsections of this proposal. It is important to realize that the GO-IRS is intrinsically a survey instrument, and thus, for each design reference case, we have intentionally focused upon a large, ambitious survey, on the scale of 30-90 nights, that can fundamentally advance our knowledge of the subject at hand. The first of these cases focuses on near-field cosmology in the Milky Way in the era of GAIA. The second considers a large survey of M33 as an example of how GO-IRS can be used to study nearby, resolved stellar populations. Finally, the third case focuses upon the potential for a large galaxy survey at z~1, similar to the SDSS.

The presentation of these cases illustrates the power of the instrument for such programs if they wish to be pursued by members of the GTC community. From a practical perspective, if the GO-IRS is approved, the instrument team will dedicate the associated guaranteed time toward a survey focused upon one or more of these science topics. Input will be solicited from the entire GTC community regarding that science which is most broadly aligned with the interests of community members, and utilize our time in a fashion consistent with the interests of the community. The goal is for any such survey to be a resource for the full community, and participation in the collaboration by all interested members. Moreover, the team would be most pleased to consider the use of the guaranteed time as a foundation for a larger, community-wide key project. Additionally, as part of any guaranteed time program, 10-20% of the fibers will be dedicated for general use for targeting objects as may be requested by members of the full GTC community.

4. Design Reference Science Cases and Technical Requirements Overview

This section describes design reference science cases summary for GO-IRS and gives an overview of the key parameters of interest for a GO-IRS-like instrument and a specific summary of the instrument requirements.

4.1. GO-IRS in Context

With GO-IRS our objective us to design an instrument that, when it comes online in 2014, will have unique capabilities that are valuable to the community in the age of new facilities such as