Brazilian Tunable Filter Imager (BTFI) Instrument Project

Conceptual Design Review (report)

IAG Universidade de Sao Paulo

2007 September 24 & 25

Review Panel:

Claude Carignan, LAE, Université de Montréal, Canada (chair)

Marco Bonati, CTIO, Chile

Dani Guzman, Durham, UK

Participants:

- **Claudia Mendes de Oliveira (CMdO), IAG - USP, Brazil (PI)**
- **Keith Taylor (KT), IAG - USP, Brazil (Project Scientist)**
- **Peter Gray (PG), Atacama Engineering Consulting, Australia**
- **Bruno Quint (BQ), IAG - USP, Brazil**
- **Giseli Ramos (GR), IAG - USP, Brazil**
- **Luiz Cavalcanti (LC), UNIFEI - Itajuba, Brazil**
- **Cesar de Oliveira, LNA – Itajuba, Brazil**
- **Ligia Souza de Oliveira, LAN – Itajuba, Brazil**
- **René Laporte, INPE – Sao José dos Campos, Brazil**
- **Francisco Jablonski, INPE – Sao José dos Campos, Brazil**
- **Henri Plana, Universidade Estadual de Santa Cruz – Ilhéus, Brazil**
- **Laerte Sodre, IAG - USP, Brazil**
- **Beatriz Barbuy, IAG - USP, Brazil**
- **Reuven Opher, IAG - USP, Brazil**
- **Videoconf: Sébastien Blais-Ouellette (Photon etc), Olivier Hernandez (LAE) & Olivier Daigle (LAE), Montréal, Canada**

Preamble:

The BTFI instrument project is directed at utilizing three relatively new technologies (Bragg Tunable Filter (iBTF), long-range Fabry Perot (FP) etalons & EMCCD detectors) for a versatile Ground Layer Adaptive Optics (GLAO) fed tunable filter imager for the Southern Astrophysical Research (SOAR) telescope. The goal of the CoDR is to review the basic concept and address the following questions:

1. Are the science goals clearly identified and validated for a GLAO-fed instrument on the SOAR telescope?
2. Does the proposed instrument concept represent an optimal strategy for achieving these goals?
3. Are the chosen concepts and technologies feasible?
4. Do alternative concepts or strategies exist that will allow the project to better meet the science goals?
5. Have the resources needed to produce a preliminary design, schedule, and budget been clearly identified?
6. Is the team ready to go forward to a preliminary design phase?

1. Introduction

During the first day, the following presentations were done to the review panel:

- Science Objectives (CMdO)
- Instrument Overview (KT)
- Performance Modeling (BQ)
- Instrument Design & Development I – Optics & iBTF (KT)
- Instrument Design & Development II – Fabry Perot & Mechanics (KT)
- Detector System & Instrument Control (LC & KT)
- Software (GR)
- Management (PG)

This was followed by a first discussion of the technical issues which was continued the next morning. Before the end of the second day, the review panel got together to discuss what was presented and to draft the following report which was completed, via email, over the next ten days.

After reviewing the presentation on each of those aspects and giving detailed comments, the review panel will make precise recommendations (in priority order) on the aspects that need to be clarified, the decisions that should be taken, and the main areas to work on between now and the Preliminary Design Review (PDR). Those recommendations will be divided in two areas: technical and management. Finally, the panel will answer to the six main questions given in the preamble.

2. Review of the Different Project Components

2.1 Science Objectives

Summary:

- The instrument combines the Fabry-Perot (FP) high spectral resolution mode (e.g. internal structures of galaxies, bars, non-circular motions) to iBTF low resolution mode (e.g. photometric redshifts). It also combined projects with medium (seeing-limited – SL) spatial resolution (e.g. dark matter studies via galaxies' kinematics) and high (GLAO) spatial resolution (e.g. AGN physics, galaxy interaction). Scientific projects involve galactic, extragalactic and high redshifts objects.
- A good initial set of science requirements have been given.

Comments/suggestions:

- **GLAO mode & SL mode** - The science team should specify clearly which scientific projects need the GLAO spatial resolution (and hence need the BTFI on the SAM port) and which projects only need SL resolution (and hence can have the BTFI on another port that should be specified more clearly).
- **Spectral Resolution –** A table should be prepared of all the projects with the spectral resolution needed to achieve the scientific goals. This could help decide which iBTF configuration is needed to achieve those goals.

2.2 Instrument Overview

Summary:

- This is a three-year project that had its kick-off meeting in December 2006, where a proposal for a new instrument was sent to SOAR. The Team's core was assembled between March and July 2007 and the FAPESP funding of Phase I was approved in June 2007.
- The concept evolution has been well explained.

Comments/suggestions:

- **VPH Performance** - The whole iBTF concept clearly appeared as the area where more work is needed. We would like to see real data on the VPH behavior/performance (prototyping is important here), because it is the most *untested/uncertain* territory.

- **Instrument's Requirements** - Clearly many very important requirements (e.g. FOV) have been frozen only very recently (beginning of September). These have to be matured and hopefully frozen well before the next PDR.

2.3 Performance Modeling

Summary:

- There was a good effort at gathering the information and attempting to get signal-to-noise (S/N) ratio simulations. We think this point is extremely important and has been correctly addressed.
- The simulations were basic but sufficient to establish a baseline for instrument performance.

Comments/suggestions:

- **Characterization of L3CCD I** - Since the detector selection (L3 v/s conventional CCD) is based on these S/N calculations, we think they require further elaboration and refinement. *Sensitivity calculations on the parameters which are unique to the L3 are fundamental*. How much the S/N decreases if the CIC (Clock Induced Charge) noise doubles? How much a change in the gain affects the S/N and flux? If we take the best selection (L3 in amplification mode?), what are the maximum tolerable CIC, Gain, Glow, etc variations for the comparison to still be favorable to the L3? That set of parameters' ranges should then be translated into controller parameters; in this way it would be clear how much is possible to tolerate from the controller for the L3 selection to still be valid. (see comments in the Detector System & Controller).
- **Characterization of L3CCD II** - This area needs significant work in the next few months before PDR, to better identify instrument limitations and to what extent they will affect science goals. A particular area of more work is related to the various detector-related limitations. For instance, dynamic range should be explored, when working in photon counting and amplification mode (L3CCD); in such cases, it would be good to experiment the effects of having a source with different flux levels, to obtain photon rate limits that would saturate in one case and achieve a minimum S/N in the other.
- **Simulation Tools** - In the same context, we think a single spreadsheet may not be enough. The effective flux and S/N depend on the flux rate (photons per second), and so the selection may not be the same in one case or the other. The BTFI team should consider the use of the simulation tools (Monte Carlo) available from Olivier Daigle, Simon Tulloch or Craig Mackay.

2.4 Optics, iBTF & Fabry-Perot

Summary:

- A new optical design should be done soon which should be much simpler since only one f-ratio (f/6.7) is now required.
- It is now also considered to use two similar etalons (for redundancy). This will depends a lot on the price of the SESO etalons.

Comments/suggestions:

- **FP Alignment** - The automated procedure to align (parallelism) the etalons have to be defined more clearly before the PDR.
- **FP Calibration** – The calibration procedure also has to be clearly worked out before the PDR.
- **Baseline iBTF Design** - it is suggested that the project adopt the “Z” iBTF configuration as the baseline and to proceed with a detailed mechanical design investigation of various mechanism design options. Since the iBTF is a critical component of the BTFI instrument, it may be worth considering prototyping the iBTF mechanism to confirm it meets the requirements. In parallel with this work the motor-encoder –controls positioning system should be investigated by the BTFI electronics engineer.
- **Choice of FOV (Field of View) –** The choice of the detector (EMCCD 1600^2) has frozen the FOV to 3x3 arcmin which will now allow to get a more definite Optical Design and take away the wide-angle problem with the iBTF
- **λ gradient & $\Delta\lambda$dead zone** – Those two potential problems with the iBTF concept need to be further explored. Resources should be identified to ask Photon etc for a more thorough detailed analysis and more quantified results on those two concerns.

2.5 Opto-Mechanical Design

Summary:

- A rough mechanical design has been presented. However, as will be discussed below, a lot of issues have to be resolved, especially with SOAR, before a more definite design is prepared. This design should be close to final at the time of the PDR.

Comments/suggestions:

- **Mass/Moment Limit -** The major technical interface issue is likely to be the maximum weight/moment that can be mounted on the SAM instrument. The current estimates vary between 60-300kgs. It is not clear if these numbers have been derived from a detailed analysis and what the consequences in technical performance or physical limits are. There does not appear to be a moment limit, however this may be important for a cantilevered instrument such as the BTFI because of the loads and deflections this may introduce on the SAM instrument. Knowing the limits to mass and moment will be important to define the possibilities of instrument configuration and structural design.

- **Space Envelope Interferences** – The current space envelope available to BTFI has a support strut which appears to pass directly through the centre of the existing instrument layout. It will be important to clarify with SOAR, as soon as possible, how this strut can be modified or adapted since it affects the instrument layout which needs to be defined to allow the detailed mechanical design work to proceed.
- **Instrument Structure –** The challenges of available mass budget and requirements for instrument stability will require the use of innovative design and materials for the instrument structure. Many modern instruments utilize a space frame approach using lightweight struts and localized stiffening in critical areas. This approach should be investigated by researching similar instruments which have been made in recent years and adopting some of their ideas. The use of carbon fiber as a lightweight, stiff material for the instrument struts and possibly some of the structural elements would be worth considering.
- **FEA Analysis** – Once the instrument structural design has progressed to an efficient structure, it will be necessary to begin a process of finite element analysis (FEA) of the design in order to further optimize the structure and confirm that it meets requirements. To make best use of FEA analysis, an optical tolerancing should be done, as well as an initial estimate of mass loads. Final FEA analysis is best done by someone experienced in the requirements of instrumentation and optics such as a consultant. However, good use could be made in early stages of the FEA capabilities in a standard CAD system by the mechanical designers. It may be beneficial to work with CTIO staff on the FEA analysis and include an analysis of the SAM instrument and the Nasmyth support structure which is interfering with the instrument.
- **Mechanism Design Work** - There is several parts of the instrument (i.e. filter/aperture slides and shutters) which are more straightforward and do not depend on the progress of investigations of the critical components. The detailed technical requirements for these components should be defined as soon as possible. Detailed mechanical design work can then proceed. This will add momentum to the instrument design phase and leave time for the later critical design work on the more challenging systems.

2.6 Detector System & Instrument Control

Summary:

- A good overview of the L3 capabilities was given. The BTFI team is aware of the most important points they will need to be dealt with.
- The BTFI team has studied most concepts associated with the detector technology chosen for the instrument, L3CCD, at an adequate level for this stage of the design, whose goal is to identify whether or not the technology will be useful for the instrument goals.

Comments/suggestions:

- **Modes of Operation -** The two particular modes of operation for this type of detector, e.g. photon counting and amplification mode, have been researched at the minimum level required to understand its characteristics, but more studies are needed to better determine which one of them is best suited for instrument scientific goals, since at the CoDR, it was evident that the initial mode selected as the best one, photon counting, was not as good as expected.
- **L3CCD Parameters** - We would repeat here something written in the previous sections. There should be a clearer study of the maximum allowed range for each L3 parameter involved, like CIC, glow, dark, temperature, gain, etc. Once the allowed range of those is known, the minimum controller performance is immediately determined. What are the maximum HV and temperature variations allowed to keep the gain inside the allowed range? Clocks/speed/CIC, bias/Glow, how precise should the temperature control be? etc. Having those parameters will allow a clear technical decision on the controller. We think there is still work to be done here before taking any decision. This is stated in the presentation, so the BTFI people are aware of it. We just want to remark **how important it is.**
- **Support & Maintenance** - We would just add that in the key areas for controller selection should appear points related to support/maintenance: how will be the post commissioning support of the controller? How much expertise there is on the chosen controller, Is it a mature, tested system? Anybody else using it? etc. These points should not decide the selection, but they should be seriously added into the equation.
- **Controllers Synchronization** - One aspect that should be added in the considerations is the potential need for controller synchronization. Since there will be two controllers reading out, there may be readout pattern noise generated. Would it be needed to share the same clock? Software synchronization? Hardware synchronization? Both? None? Just aspects to have in mind that were not mentioned.
- **Impacts of CIC** - From L3CCD articles, it is expected that CIC noise will be of great importance when trying to image very faint sources, therefore it is important to quantify the effect it will have on the instrument performance,

more than quoting other group's numbers, but assessing how different CIC would impact science goals. It is advised to present thorough simulations of L3CCD behavior at PDR, followed by real detector characterization for CDR.

2.7 Software

Summary:

- The general architecture presented is compatible and makes sensible use of the SOAR environment; this is an important point that has been correctly considered.
- Also the general needs of the software seem to be very clear and on the right path.

Comments/suggestions:

- **Data Handling** - The software presented has only relation with the handling of the instrument (detector and mechanism control and monitor). This is of course a fundamental part, but there is another part related to the data pipeline and reduction: once a FITS data file has been produced, what will happen to it? Where will it go? What kind of reduction would be made? On site? In real time? On a dedicated machine? We do not expect that there should be clear answers to this at this stage, but the considerations should be made explicitly.
- **Calibration** - The same goes for the calibration procedures. It was stated explicitly on some presentation that this will be fundamental, and we know the BTFI team is well aware of the importance of this, but it was not mentioned in the software section. This should also be explicit somewhere (what resources to use for this?, where to find the expertise?, etc)
- **On-line Reduction** - One feature that seems to be missing and could be added to the acquisition software is a window for on-line reduction of the data. This window can be updated after each cycle (complete number of channels) to allow determining precisely when an observation has sufficient signal-to-noise (S/N) ratio such that it can be stopped. For one thing, it prevents obtaining under exposed observations. Moreover, this is the optimal way to get the best possible quality data without loosing time with unnecessary long exposure times when the S/N of the data allows to reach the scientific goals (e.g. velocity field for rotation curves determination; profiles for abundance studies, etc). Such a system is in use with scanning FP systems such as FaNTOmM (OMM & CFHT)), CiGALe (OHP & La Silla) & GHaFaS (WHT).

2.8 Management

Summary:

- A very well-developed management plan has been presented with a well organized way to keep track of the different documents produced which should be easily available to the project team.

Comments/suggestions:

- **Public Relations** - It is suggested to maintain a public area of the BTFI web site that would give general information to the scientific community at large.
- **BTFI-SOAR ICD –** It will be important to start developing a proper ICD(Interface Control Document) between the BTFI instrument and SOAR. The majority of the issues at this stage are likely to be mechanical since the electronic, software and optical interfaces are reasonably well understood and just require documenting. It is suggested to develop a straw man ICD first, with TBDs which can identify what aspects require further investigation. The mass/moment limits and the space envelope and physical interferences (*see comments below*) are likely to be the main issues.
- **Close Liaison with CTIO/SOAR –** A close technical relationship with SOAR should be developed as soon as possible. This will be important in the next design phase as detailed issues are investigated. It should be a collaborative working relationship where problems and issues are worked out jointly. It would be good to get SOAR to officially appoint a CTIO person as a BTFI technical liaison responsible.
- **Project Mechanical Staff** – In order to progress further with the instrument's opto-mechanical design a project mechanical team needs to be set up. There is sufficient work in the next months to utilize full-time a mechanical engineer and a mechanical detailed designer. It is important to formally establish this group as soon as possible.
- **Detailed Mechanical Design Schedule** – A detailed plan and schedule for mechanical design work over the next months should be developed which makes use of the mechanical resources of the project's mechanical staff and coordinates with the progression and definition of the instrument's critical components i.e. optics, Fabry-Perot and iBTF, as well as the more straight forward aspects of instrument mechanisms and structure.

3.0 Recommendations

3.1 Technical

- It is recommended to sort out, as son as possible, with the SOAR people the maximum weight that can have the BTFI, since this has a large impact on the mechanical design.

- It is recommended that the mechanical design takes well into account the two ports where the BTFI could be used (two modes: GLAO and SL).

- It is recommended to sort out as soon as possible what will be the exact contribution of the company Photon etc in the iBTF module (From conceptual studies up to producing the whole module).

- It is recommended that the science (project vs resolution) should really be what decides the iBTF configuration (1 or 2 VPH, reflection vs transmission). Because it is a completely new technology, prototyping is highly suggested before building the finite module.

- It is recommended to identify resources to do Finite Element Analysis (FEA) studies of the instrument structure and of the BTFI/SAM assembly.

- It is recommended, before the next PDR, to continue gathering information on the two possible types of controllers (LAE or SDSU) that could be used for the EMCCD detectors. As much laboratory tests and simulations should be obtained for both types of controllers.

- It is recommended that the software group add to the acquisition software data handling software and a window for on-line data reduction.

3.2 Management

- It is recommended to hire a project manager (PM) as soon as possible. This could be a full-time job or at least 3 days/week.

- It is recommended, before the next PDR, to identify clearly all the sources of financing and of manpower, and this until the end of the project.

- It is recommended to hire a mechanical engineer and mechanical detailed designer as soon as possible.

- It is recommended to identify, as soon as possible, the resources (workshop, manpower) to actually build the instrument and the location and schedule of the instrument integration.

- It is recommended to clarify as soon as possible the participation of the LNA and of INPE into the BTFI project.

- It is recommended to establish a strong communication link between the BTFI project group and the proper representative of the SOAR telescope and SAM team. Regular exchanges should happen from now on between the two groups.

- It is recommended to make a few presentations on the BTFI at the next SPIE meeting on Astronomical Instrumentation, to be held next June in Marseille, to make the instrument well known to the international Astronomical community.

4.0 Concluding Remarks

Let us now try to answer the initial six questions to which the CoDR review committee is supposed to give answers.

1. ***Are the science goals clearly identified and validated for a GLAO-fed instrument on the SOAR telescope?***

Clearly the BTFI team has well defined the different science areas that can benefited of such an instrument. They only need to specify better which of those projects only need SL spatial resolution.

2. ***Does the proposed instrument concept represent an optimal strategy for achieving these goals?***

According to the committee, the approach of developing both the low and high spectral resolution, while at the same time having the possibility to have high (GLAO) and medium (SL) spatial resolution is the optimal approach.

3. ***Are the chosen concepts and technologies feasible?***

While the new etalons developed by SESO should deliver the performances needed for the BTFI, the iBTF concept still need much more theoretical and prototyping work before being able to say it is really feasible. More practical and theoretical work is also needed on the FP and detector controllers, before a definite answer can be given.

4. ***Do alternative concepts or strategies exist that will allow the project to better meet the science goals?***

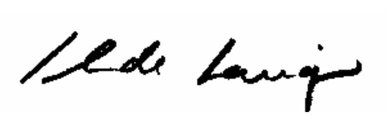
I think that the actual design should meet all the science goals given in the science objectives presentation.

5. ***Have the resources needed to produce a preliminary design, schedule, and budget been clearly identified?***

This is the area that needs the more work (see the comments in the different sections). Much more resources have to be identified, especially on the mechanical side. The budget situation also has to be clarified

6. ***Is the team ready to go forward to a preliminary design phase?***

The answer here is definitely: **YES**.



Claude Carignan, chairman
For the Conceptual Review Committee

October 5, 2007.