Laser Frequency Comb at SALT

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1 Description of the project

Following an email from Ray Sharples, we have been in contact with two researchers from the department of ultra fast optics at the University Heriot-Watt in Edinmburg, Scotland : Derryck Reed, who heads this department, and Richard McCracken, postdoctoral researcher in his group.

They have built a highly tunable Laser Frequency Comb and were looking for a High Resolution Spectrograph to test their latest prototype. Both Lisa and I thought that this is an incredible opportunity for SALT, and we have decided that some discussion with Derryck and Richard was needed, in order to understand better their needs, and their goals.

We had a long skype call with them, during which we clarified many aspects of the project, both from their part and ours. The main reason they want to test their comb on SALT is to prove that it can be used on a telescope. Since every next ELT will have one comb for their high resolution Spectrograph, this will allow them to participate in the call for bids for such calibrator.

Once we had a better understanding of their needs in terms of logistical and personal support we had long discussion with Mike to present him the project. We then and a discussion with Ted and Amanda to do the same.

The major outcome of these discussions was that the scope of the project changed. Initially, Lisa and I thought that the presence of the comb could be justified from a purely instrumentation and PR point of view. But the project now includes a strong scientific part as well.

The project can now be outlined as follows.

- Transport phase : from now to early january 2016
- Installation/commissionning phase: from early 2016 (ideally, as early in january as possible) to end of march 2016
- Scientific use : from April to June 2016.

We have started the first phase, by contacting the import company that helped Durham ship parts for HRS : International Forward Services. They have provided excellent service to us and know what needs to be done to import scientific equipment to South Africa.

The second phase will take place at SALT. The installation of the comb will be done by Richard and Derryck, who will come to SALT. The duration of their stay is still to be decided, but it's likely they will be here for the whole duration of this phase. It is to be noted that they have a grand from the STFC (Science and Technology Facility Council) that covers all their expenses for the installation of their comb at SALT. This includes their travel and the purchase of some missing equipments. The complete list needs to be finalised, but some items, such as the fibre the will link the comb to HRS, have already been identified. During this phase, some local support will be provided to Richard and Derryck. Lisa and myself will spend some time at SALT for that specific purpose.

The third phase will then start with the comb being used for scientific observations. In order to get a significant set of data, we requested from Derryck that the comb stayed at the telescope for 3 months. The amount of time dedicated to using the comb will be on the order of 15h and will come from the engineering time reserve.

2 Cost estimates

The cost of this project can be split in two different parts:

- direct costs for SALT. They should be very limited. The comb will come as a standalone device, and Edinburgh will bring along the equipment they need. This includes the 15m (TBC) long fibre that will link the comb to HRS, and some electronics equipment that is required for the operations of the comb.
- indirect cost for SALT. These will be more significant. Derryck and Richard will be at Sutherland for the whole duration of the commissioning (the three months period between January and March), and they will need some support. Lisa and Éric will provide some by spending a significant amount of time with them during that period. There will also be some support needed by TechOps to do the modifications (that are still TBD) to the fibre injection bench to accommodate the extra fibre.

3 Impacts on SALT operations

The modifications to HRS will be reversible. Once the comb is uninstalled, HRS will perform exactly as before. From that point of view, the comb will have no impact whatsoever on the operations of the telescope. The impact will be on the High Stability mode of HRS. The disruption will be kept at a minimum, the modifications will be done during the day, and the commissioning and verification will be done during the day too, mitigating the impact on science time. There will be no impact on the operations of RSS and SALTICAM, since no modifications to the Payload need to be done : everything will be held in the HRS outer electronics room. It will have to be defined how the comb is operated simultaneously with HRS, when the science data are taken. The Tracker Upgrade was Initially planned to happen in April. During that time, the telescope will be unavailable, and it seems to be suboptimal to have the comb and the telescope down at the same time. Raoul Van Den Berg sees no problem in moving the upgrade a couple of weeks earlier. The two projects will then collide, and a careful planning needs to happen since the same people will be needed for both. But the comb will require way less people than the tracker, so it seems entirely feasible to have both projects run in parallel.

4 Science

It is not yet defined how the papers using the data from the comb will be published, but an option is that they would form a series of Observatory Papers that will describe what science can be done with a comb, and show the (preliminary) results that one can expect with such a calibration device. The call for proposal need to be defined. It is important to define before the call is issued if there are to be restriction to whom can submit a proposal. We currently have four projects that have been suggested by scientist from institutions outside the SALT consortium. Do we want more of those or should we restrict ourself now to scientists from the consortium? This question needs to be addressed too.

4.1 Potential projects

The obvious use for laser frequency combs is the detection of exoplanets. But these need observations over a long period of time, and are not suited for our campaign. We have thus found what other science could be performed in those 3 months, and curently, we have four projects that can make use of the combs and do not require observations over a long period of time :

- followup of K2 stars, specifically from the fields of Campaigns C2 and C7, either stars with planets, or very young ones,
- lines profiles in BE stars
- isotopic ratios. Measuring ^{6}Li/^{7}Li, ^{24}Mg/^{25}Mg/^{26}Mg with accurate wavelength calibration
- Obtaining time series on a loose base for hot variable stars.

These projects were suggested by scientists who were contacted directly by Amanda and Éric.

But it would be better for the SALT community to be able to propose programs directly, and thus, a call for such programs will be made. The details for such a call need to be defined.

4.2 Data reduction

In order to produce some science, it is mandatory that we are able to reduce the data properly. We already have a pipeline that is able to reduce data for MR, in a way that satisfies the users. The main difficulty when turning to the High Stability mode, is that the production of the wavelength calibration is anything but a trivial process. Among the many reasons is the fact that to derive the position of the lines of either the iodine cell or the ThAr lamp, it is key to have an excellent understanding of the physics of the source. Without this in depth understanding of the source, it is virtually impossible to produce the (pixel, wavelength) relation. The use of the frequency comb removes the need for this knowledge, since the many lines of the iodine or of the ThAr are replaced by much more equally spaced dots on the CCD. Each dot has no internal structure, they are all equally spaced, and they show slow variations of intensity. Thus, it's (at least in theory) much more easy to derive the wavelength solution for each order. And overall, the wavelength calibration overall is much simpler.

Since we have the experience on the reduction of HRS' data, we may be better placed than anyone else to do reduce the data ourselves, but this needs to be clarified also, since it adds to the overall workload of SALT/SAAO astronomers.

5 Benefits

The benefits for SALT will be multiple.

SALT will be the first large telescope to ever host a laser frequency comb. In these times of difficult search for new partners, it can be beneficial to show that SALT is attractive for cutting edge technology, and that its potential for development is still intact.

Building strong relationship with teams around the world who are developing instruments, and proving that we are willing and able to be their real-life test bed, and that we can both benefit from collaboration is not to be overlooked either, in the prospect of mid to long term improvements to SALT. We will also learn a lot in terms of technology and instrumentation by having had for a few months a device that is really at the edge of what is technologically feasible nowadays. This will make us a potential good partners for instrumentation developments.

The science outcome will be huge. Laser frequency combs are usually used to detect exo-planets. We will show that they can be used for many more astrophysical fields, and we will be the first, once again, to do so. The main reason it hasn't been done so far is because there is only one frequency comb installed at a telescope, and this telescope has one instrument, HARPS, dedicated to planet search.

Overall, all these will be easily advertised, and we will be able to get some nice and unique PR out of it. This will put back SALT at the centre of the astronomical world, and will help us in the long process to reverse the bad image that SALT has.