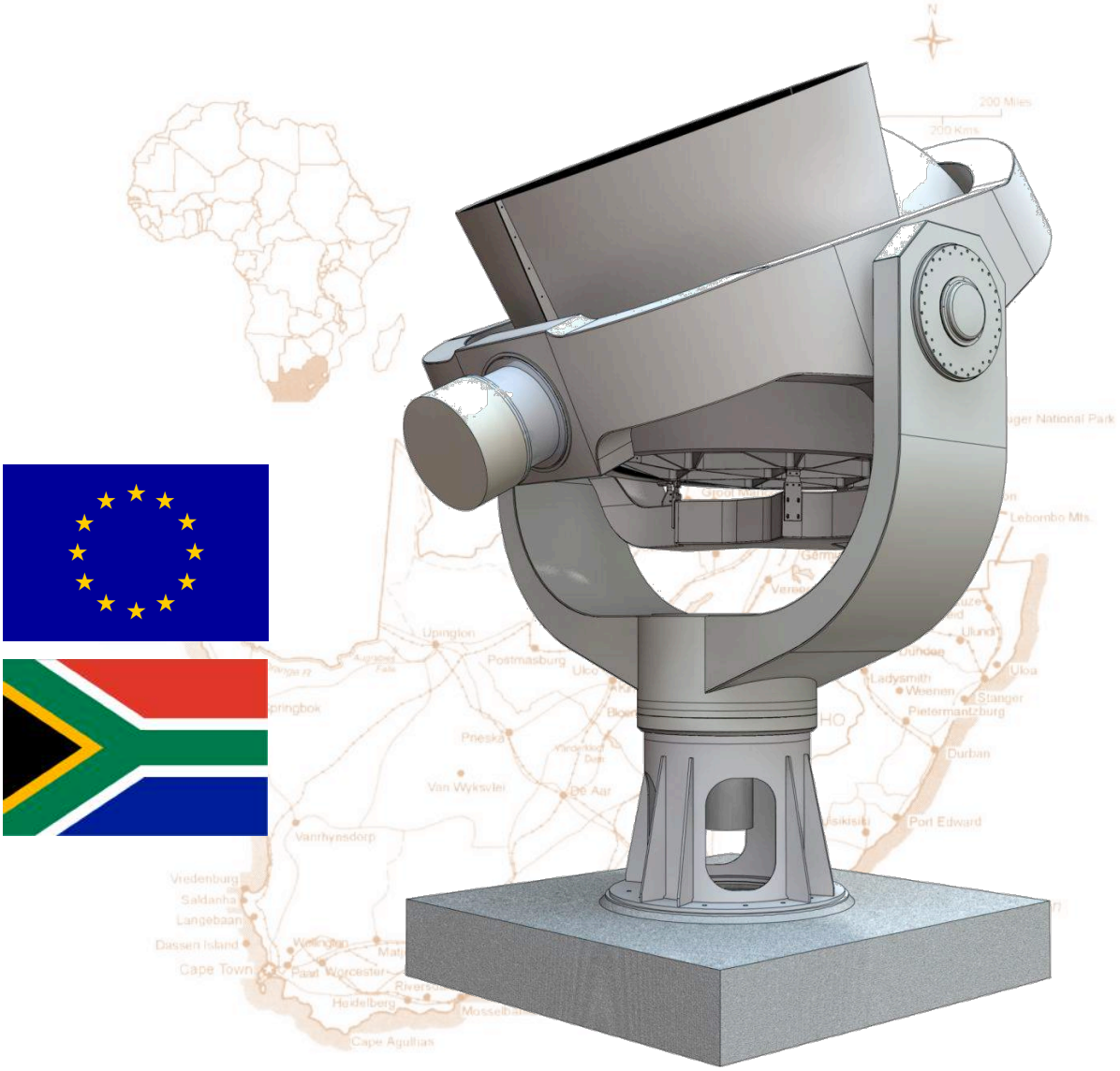


QUIJOTE-South
in the Karoo. South Africa

INDUSTRIAL AND SOCIO-ECONOMIC ASPECTS

April 2014

SUMMARY

The QUIJOTE (Q-U-I JOint TEnerife) CMB Experiment is a scientific collaboration between the Instituto de Astrofísica de Canarias (IAC), the Instituto de Fisica de Cantabria, the Departamento de Ingenieria de Comunicaciones (Santander), the Jodrell Bank Observatory (Manchester, UK) and the Cavendish Laboratory (Cambridge,UK). It consists of two telescopes and three instruments dedicated to measure the polarization of the microwave sky in the frequency range between 11 GHz and 42GHz, and at angular scales of 1 degree.

From a scientific point of view, the QUIJOTE Experiment is groundbreaking: the characterization of the B-mode signal in the CMB polarization with high sensitivity is of fundamental importance for cosmology, and in general for Fundamental Physics, as it allows to confirm the inflationary scenario, and to study the underlying physical conditions of this period that occurred only 10e-32 s after the Big Bang. These physical conditions are supposed to be dominated by energies of the order of 1e16 GeV, orders of magnitude higher than the maximum energies accessible at the Large Hadron Collider at CERN (of the order of 1e4 GeV).

The extension of the project to **South Africa** would bring the great advantages of full sky coverage and the increase in sensitivity by duplicating the number of detection elements.

Since this country is fully committed to facilitate investment in universe sciences to ensure their competitive in astronomy, the international leadership of their observatories as well as to diversify the economy and open new opportunities for people and companies (training, employment, technological development), the current collaboration propose to develop a set of experiments in South Africa in combination with observations from the Canary Islands, covering both hemispheres, and providing the first all-sky survey of radio-microwave polarization in the still not fully explored frequency range 10-40 GHz.

The **University of the Witwatersrand (Johannesburg, South Africa)**, would be the node in South Africa, internationally renowned for its commitment to academic and research excellence. With talented students and distinguished academics, Wits University contributes to the global knowledge economy and local transformation through generating high level, scarce skills and innovative research. Its participation in the QUIJOTE South project will be an asset for the feasibility of the project and a warranty to maximize the socio-economic return of this proposed collaboration with Europe.

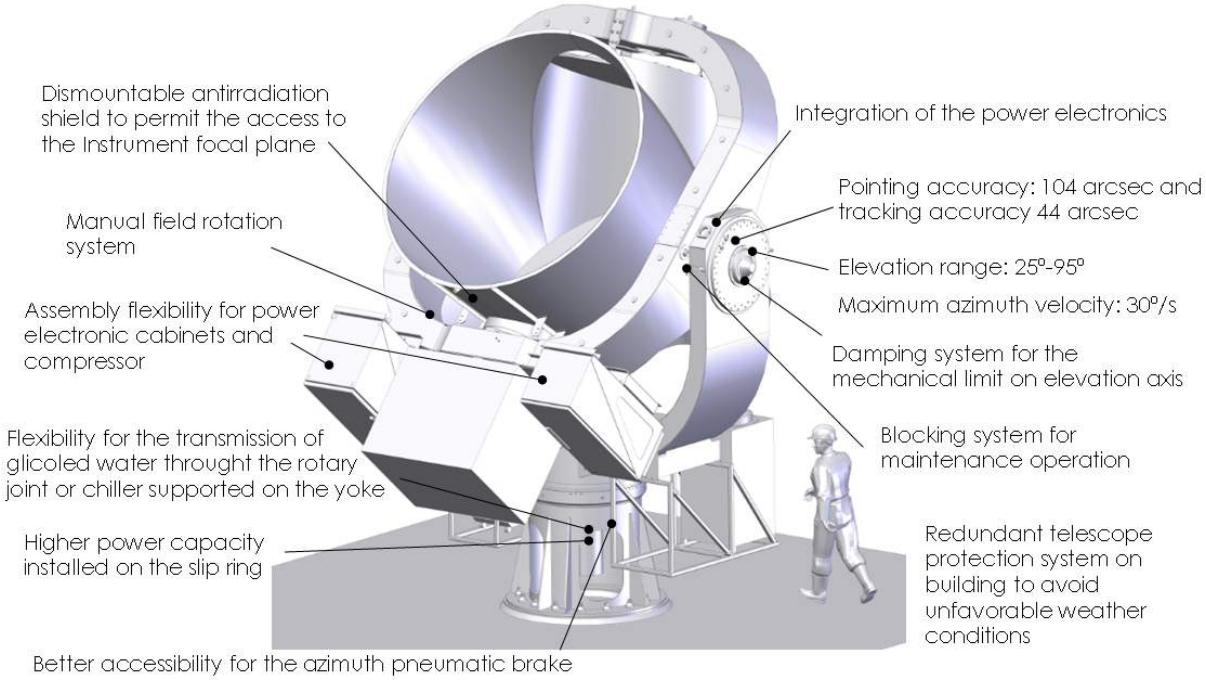
INDUSTRIAL AND SOCIO-ECONOMIC ASPECTS OF QUIJOTE – SOUTH

The extension of the project to South Africa would consist of two phases:

Phase I: to replicate one of the QUIJOTE telescopes and to build a new MFI (10-20 GHz) instrument. The QUIJOTE telescope is designed to provide polarization sensitive observations up to 200 GHz. To deploy this new telescope and instrument in a South African observing site with the goal to obtain a full Southern Hemisphere survey of 20000 sq. deg with a sensitivity of 10 microK per beam. In combination with the data of QUIJOTE from the Northern site, it will provide a Q, U and I high-sensitivity full sky coverage at four frequencies 11, 13, 17 and 19 GHz. These full sky maps will be the most sensitive ever obtained at these frequencies and will be used to investigate the polarization properties of the synchrotron emission and other possible contaminants from our Galaxy. The construction of the telescope and instrument will take 1 year. After it, only 1 year of data will be sufficient to obtain maps at the four frequencies with a sensitivity and resolution better than WMAP (NASA satellite) at 22 GHz.

Phase II: to build one interferometer of 100-elements operating in the frequency range 30-40 GHz. This interferometer would be deployed two years after the start of operations of the QUIJOTE telescope in the South African site, and is aimed to carry out very sensitive measurements with noise level of 1 microK / beam in selected low galactic emission regions covering a total of 5000 sq deg in each Hemisphere. This set of two interferometers in both hemispheres can provide a confirmation of the B-mode signal at if r=0.01 one year after the beginning of the observations, therefore improving by at least a factor 5 the sensitivity of the current QUIJOTE imaging facility at the North Hemisphere, and by a similar factor the sensitivity of BICEP2, an experiment that very recently reported the first detection of this signal.

MAIN ELEMENTS OF ONE OF THE THREE TELESCOPES



The consortium is convinced of the socio-economic benefits that the project could bring to South Africa, and in particular to the region of the Karoo. First of all, it is remarkable that this proposal has wide and strong scientific and technological synergies with the ongoing MeerKAt and future SKA radio experiments, which survey the sky at slightly lower frequencies, and strong synergies with the South African Human capital development program. In addition, training of South African MSc and PhD students, post-docs and engineers in conducting observations, data analysis and on the construction of advanced instrumentation in radioastronomy will be feasible from the very beginning (Phase I) of the project. South African staff can immediately participate in the current experiment via extended visits at the Teide Observatory and to the IAC headquarters in the Canaries where the observing programme has already started and a new telescope and two instruments are going to be assembled before the end of next year. Training in specific technical and scientific aspects of the project can also be acquired in the other institutes/universities of the Consortium where diverse subsystems for the imagers and for the interferometers, and specific software packages for data reduction and analysis are being developed.

It must be made clear that South Africa, with its research centres and universities, is sufficiently mature and experienced to participate in the scientific exploitation of this major experiment at the same level of the other involved countries. A clear sign of this is the strong involvement of South Africa in other major radioastronomy projects such as MeerKAt and SKA. In addition there will be a direct technical and economic impact on the region hosting the telescope and other actors of the country. Science in South Africa will benefit from this project but there will also be benefits in other areas like employment, economy and industry. Briefly, the potential impacts are as follows:

- Siting Quijote South in the Karoo will directly result in the creation of several highly skilled jobs. Around 25% of the expected budget (6 M€) will be dedicated to cover the salaries of 6 employees, predictably 2 postdocs, 2 PhD students and 2 engineers. Half of this personnel will be located in South Africa, therefore opening clear opportunities for South African. The other half will in principle be based in the IAC, or in the other institutions of the Consortium, but potentially could also be of any African nationality.

- Siting Quijote South at the Observatory of Karoo will benefit and reinforce the basic and advanced infrastructures at the observatory. The support facilities at the site are being improved and updated regularly in order to attract new research infrastructures for observational astronomy.

- Building and operating Quijote South at the proposed site will bring economic returns for the Karoo proportionate to consumption from these activities, especially during the operation phase, and will encourage the development of new infrastructure and services as they are needed.

- If Quijote South is sited in South Africa, it will encourage young people to take up scientific vocations, bolstering the training and retention of young people in highly specialised areas of physics, astronomy and engineering. In particular, the Wits University maintains and seeks out new partnerships with other universities on and beyond the African continent, through its Internationalisation and Strategic Partnerships Office (ISPO). Such linkages, and the fact of working closely with academic departments, allow ISPO to facilitate opportunities for Wits staff and students to participate in research collaborations, student and staff exchanges etc. with international partners. All the partner institutions clearly reach out the research South African community to take advantage of

the expertise already gained by the European research institutions. The postdocs and PhD students will be responsible for the operations of our telescopes, and of the data reduction, data processing and scientific analysis of the data. The members of our collaboration have wide experience in these aspects, which has been acquired with the telescopes that we are currently running (and have ran since the 80s) in the Northern hemisphere, and will transmit this experience. These postdocs and PhDs could make, from the beginning of the project, extended visit to our institute, where the observing program is already ongoing, or to other institutes of the consortium. This has an important synergy with MeerKAT and SKA, as the tools that are used to extract the scientific information from the data are very similar. Also, it must be noted that many of the skills (software writing, big data analysis, the use of specific statistical tools, etc.) that are used in our field, and that will be acquired by these postdocs and PhD students, have direct application in the industry.

- The engineers that would be hired by the project would be working on several technical aspects, like the design of the telescope, or the design and fabrication of receivers. Different members of our collaboration have an accumulated experience of over 30 years in the development of radioastronomy instrumentation, and will train these new-hired engineers in the specific aspects of our project. This has an important synergy with other bigger projects that are being developed in South Africa like MeerKAT or the future SKA. In fact, these experiments observe in the same frequency range and, like one of our telescopes, use interferometry, and therefore very similar technology. These engineers would then get training in different technical aspects that will be very valuable for these projects. It must also be noted that many of the instrumentation that is used in this field has also a direct application to industry, in particular to radio communications.

Quijote Experiment at Teide Observatory

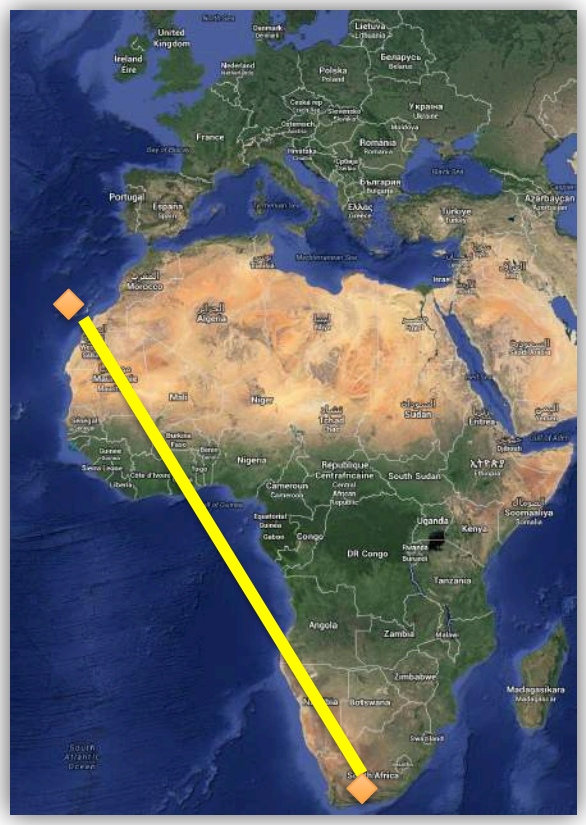
- Around 70% of our budget will be dedicated to the fabrication of the telescope and of the instruments. It is expected to build a significant part of this instrumentation in Europe, but involvement of African industry is also

considered. In particular, some hardware (like for instance electronic cards or mechanical pieces) could be built locally in South Africa, and therefore be contracted to local companies.

- A fraction of the total budget, around 300 Keuro, will be dedicated to civil works in place (foundations, fabrication of the enclosure of our telescopes, the dome, adjacent buildings hosting the laboratories and control rooms, etc). These works will be contracted directly to local companies, and therefore will have a direct return on local economy.

- As a result of this collaboration, the staff of our collaboration in Europe will make regular visits to South Africa, during the installation of our telescopes, and also during the scientific operation. This will have an obvious impact in the local economy, as a consequence of the expenses on accommodation, food, etc.

- This collaboration will allow bridging both Observatories in South Africa and the Canary Islands respectively, strengthening strategic links between both locations not only in the field of radio-astronomy but also offering new opportunities of collaboration in other fields of research (optic, solar physics, etc.). The excellent astronomical quality of the sky over the Canaries, which has been comprehensively characterised and is protected by Law, makes the two Observatories of the IAC an "astronomy reserve", which has been open to the international scientific community since 1979, as a result of the Agreements for Cooperation in Astrophysics. Exchange of best practices and strategic alliances could be also proposed.



Location of the Sites hosting the QUIJOTE Experiment (Teide Obs. and Karoo Obs.)

- An important part of academic research is the dissemination of the scientific results and corresponding public outreach. We plan to contribute to the local initiatives of communicating astronomy to the public. This will have an obvious cultural impact on civil society and potentially in the development of tourism. First of all it will contribute to consolidate the social perception of the Karoo's population on the importance of the Observatories and their telescopes present and future. They see the Observatories and the quality of the sky as an opportunity for creating quality tourism in the region, by targeting visitors who are interested in astronomy and observation. Moreover, building and operating Quijote South will provide new opportunities for astronomy education (student competitions, tele-astronomy workshops, educational material, exhibitions, documentaries, children's theatre, digital newspapers...) by specialist publishers, schools, science museums and planetariums.
