



T-REX: education and formation

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Abstract. An important goal of the T-REX project is the creation and the formation of new experts and professional profiles with extremely high specialisation to prepare tomorrow astronomers and instrument scientists that will take full advantage of E-ELT and that will make the Italian participation a success. The existing tight interaction and integration between INAF institutes and universities as allowed the T-REX Project to fund and support a total of 4 PhD grants. Here we briefly summarise their present and future activities.

1. Introduction

T-REX (Telescope to Reach the EXtreme) is the *Progetto Premiale* funded for two consecutive years by the Italian Ministry for Education, University and Research (MIUR) in order to support the Italian participation to the European Extremely Large Telescope (E-ELT), 40m-class telescope which will be constructed by the European Southern Observatory (ESO), will cost about 1.1 billion Euros and will have its first light no earlier than the end of 2024. E-ELT is the infrastructure with the highest priority for the European astrophysical community, and will be the largest telescope in the world. Italy has been among the first ESO member states to approve the E-ELT and as such will have an important role in its construction.

Within this framework, the main goals of T-REX project are to *promote research, technology and formation activities in a coordinated way, with the aim of developing new frontier technologies useful for the entire national and*

international science communities, as clearly stated in the two proposals which have been submitted to MIUR.

E-ELT is a long term project with important features which have to be taken into account such as:

- it will have its first light roughly in ten years from now;
- it will be the first telescope to fully rely on Adaptive Optics (AO);
- it will require the development of “extreme” technological solutions.

Clearly, apart for the expected groundbreaking scientific results, the full success of the Italian participation will also require a perspective technological transfer to national industries. The key to success is therefore the development of advanced instrumentation which, given the timescales of the project, can only rely on science and technology researchers educated since the beginning of the PhD. A wide involvement of the younger generations at the graduate and post-graduate level is then re-

University	Laurea Triennale (Bachelor)	Laurea Magistrale (Master)	Dottorato (PhD)
Bologna (Dept. Physics & Astronomy)	Astronomia	Astrofisica e Cosmologia	Astrofisica
Catania (Dept. Physics & Astronomy)	Fisica	Fisica	Fisica
Florence (Dept. Physics & Astronomy)	Fisica e Astrofisica	Scienze Fisiche e Astrofisiche	Fisica e Astronomia
Insubria (Dept. Physics & Mathematics)	Fisica	Fisica	Fisica e Astrofisica
Padua (Dept. Physics & Astronomy)	Astronomia	Astronomia	Astronomia

Fig. 1. Universities involved in the T-REX project with the names of the relevant Departments, Bachelor, Master and PhD Courses.

quired to prepare tomorrow astronomers and instrument scientists who will take full advantage of this 1.1 billion Euros facility. All of this can be translated in an important goal of T-REX: *the creation and the formation of new experts and professional profiles of extremely high specialization*. The related activities are the topic of this paper.

2. Synergies between INAF and universities

The creation and the formation of new experts and professional profiles of extremely high specialization can only be achieved through a close interaction and integration between INAF institutes and the local universities. Limited only to the T-REX project, these are

- Osservatorio Astronomico di Bologna, IASF-Bologna \longleftrightarrow University of Bologna;
- Osservatorio Astronomico di Catania \longleftrightarrow University of Catania;
- Osservatorio Astrofisico di Arcetri \longleftrightarrow University of Florence;
- Osservatorio Astronomico di Brera, IASF-Milano \longleftrightarrow University of Insubria;
- Osservatorio Astronomico di Padova \longleftrightarrow University of Padua.

The requested close interaction and integration between INAF institutes and universities is already existing since many years in Italy, even

before the creation of INAF itself: INAF researchers provide a strong and much needed support to didactic activities by teaching in master courses, by being master and PhD thesis advisors and by being part of PhD supervising committees (Collegio dei Docenti). The astronomers in the universities, on the other hand, provide significant contributions to INAF activities and their role is officially recognised as most of them are “Associated to INAF” and can use INAF resources for research activities. The INAF support has been important in allowing “Astronomy” or “Astrophysics” to be present in almost all the official names of Departments, Bachelor, Master and PhD courses, as shown in Table 1 (this table is limited only to the universities participating to the T-REX project).

3. Education and training

As a result of the efforts of the astronomers in the universities, and thanks to the support by the T-REX project, E-ELT related teaching activities have been present in all three levels of education (Bachelor, Master, PhD) with the results that, at least in the participating universities,

- Physics and Astronomy (or Physics) students know about the E-ELT since their Bachelor studies;
- E-ELT specific lectures and/or seminars on science and instrumentation are routinely given at Bachelor, Master and PhD level;
- Bachelor and Master thesis on scientific and technical topics related to the E-ELT have been or will be discussed.

It is beyond the scope of this paper to enter into the details of E-ELT related training activities at the Bachelor and Master level since the most important effort in T-REX is the training of PhD students.

Before continuing, it is important to provide a very brief description of the Italian PhD for the sake of those readers who have not been in contact with the Italian academic courses. This description will be focused mostly on PhD courses in Astronomy and/or Physics (those relevant for the scope of this paper) but

most of the things are general features of the Italian PhD. In Italy access to all PhD courses is through an open competition called “concorso”. The duration of the PhD is three years and in almost all cases the student is supported by a grant paid directly by the university or with external research funds which, for instance, can be provided for by INAF. The PhD Thesis must be submitted at the end of the third year. The work during the PhD in Astronomy and/or Physics consists mostly of research activity (scientific and/or technological) under the supervision of a tutor. Depending on the university, there are courses to be followed during the first and, possibly, the second year and the participation to national and international schools is strongly encouraged. A three years fellowship has a cost of about 60,000€ and, adding the direct costs related to the research activity, each fellow corresponds to an investment of the T-Rex program close to 100,000€.

In the T-REX project there has been an initial request of 7 PhD grants following the second call for proposals (in the first year the possibility was not specifically mentioned). The final money allocation required, as usual, a significant remodulation of the expenditure profile and 4 PhD grants were eventually assigned: 1 for OU3 at the University of Bologna, 2 for OU4 (1 during first year of project) at the University of Florence and 1 for OU4 at the University of Insubria. We now briefly describe the PhD activities of the students which eventually won the grant assigned by T-REX.

3.1. T-REX PhD@Bologna

The grant has been assigned to Mauro Patti who is working on a thesis on *New concepts and technologies for adaptive optics on the European Extremely Large Telescope* under the supervision of Emiliano Diolaiti, from INAF–Osservatorio Astronomico di Bologna. The PhD work is focussed on the development of a laboratory prototype for the experimental investigation of specific algorithms and calibration strategies for laser guide star wavefront sensing and on the analysis of the optical and mechanical design of the E-ELT MCAO module to define proper integration and calibra-

tion procedures. Since the grant is funded by T-REX and therefore by INAF, it is important to mention that the agreement between INAF and the University of Bologna allows INAF Researchers to be part of the PhD Committee and to be formal supervisor of a PhD Student.

3.2. T-REX PhD@Insubria

The grant has been assigned to Matteo Genoni who is working on a thesis on *Strumentazione E-ELT Sviluppo tecnologici, strumentali ed interpretativi* under the supervision of Filippo Zerbi and Marco Riva, from INAF–Osservatorio Astronomico di Brera. The PhD work is focussed on: (1) the optical design of an E-ELT HIRES (HIRES is the high resolution spectrograph for E-ELT with Italian PI-ship) comparing existing and developing new architectures and technological solutions; (2) the development of optical paraxial parametric model for a broadband HIRES at E-ELT to be exploited at a system engineering level. In addition the work foresees data reduction analyses to derive models for the super massive black hole (SMBH) mass estimation in active galactic nuclei (AGN) from medium and high resolution single epoch spectra. It is important to mention that University of Insubria allows any INAF Researcher to be the formal supervisor of a PhD Student; 4 INAF Researchers are part of the PhD committee.

3.3. T-REX PhD-1@Firenze

The grant has been assigned to Sara Faggi who is working on a thesis on *HIRES - E-ELT Science Case for astro-biological relevant targets: comets* under the supervision of John Brucato, Gian-Paolo Tozzi and Ernesto Oliva from INAF–Osservatorio Astrofisico di Arcetri. The aim is to develop a new Science Case for the Solar System related to astrobiology, with particular attention to comets. The proposed topics that are being developed are the following: (1) the origin of Earth’s oceans: investigation of isotopic ratio of water (D/H) through different class of comets in order to understand the origin of Earth’s oceans; (2)

comets as vectors of organic compounds: investigation of organic molecules as CN, C₂, C₃, NH₂ to evaluate the delivery of organic molecules to young Earth; (3) classifications of comets: investigation of parent molecules and radical species and their ortho-para ratio (OPR) to characterise chemical diversity in comets in order to understand Solar System's formation and evolution.

In order to properly develop the science case for HIRES, an operative setup has been arranged as follow: in February 2015, the team acquired a comprehensive high resolution spectral survey of comet C/2014 Q2 (Lovejoy) in the 0.9-2.5 μm range, with GIANO - the near-IR spectrograph on TNG (the Italian Telescopio Nazionale Galileo). These observations opened new pathways for cometary science in the near-infrared spectral range (0.9-2.5 μm) and established the feasibility of astrobiology-related scientific investigations with future high resolution IR spectrographs on 40-m class telescopes, e.g., the HIRES spectrograph on the E-ELT telescope.

3.4. T-REX PhD-2@Firenze

The grant has been assigned to Mirko Curti who is working on a thesis on *Dynamical and Chemical Evolution of Galaxies with Adaptive Optics Observations* under the supervision of Simone Esposito and Filippo Mannucci from INAF-Osservatorio Astrofisico di Arcetri. The PhD work is structured in three parts. (1) The Science commissioning of ARGOS+LUCIFER@LBT; ARGOS is the Ground Layer Adaptive Optics (GLAO) system for LUCIFER 1 and 2 at the Large Binocular Telescope (LBT, a telescope

with a significant Italian participation). (2) Extragalactic MOS Observations with ARGOS+LUCIFER to study Galaxy assembly over cosmic time, the Physical processes which drive the relationships with gas metallicity and the Role of stellar and AGN feedback. (3) Preparation for the E-ELT with the optimisation of data analysis methods for AO observations (based on the activities of 1), the development of Science Cases for ELT-CAM and ELT-MOS instruments (based on the activities of 2).

Finally, it is important to mention that University of Florence allows any INAF Researcher to be the formal supervisor of a PhD Student; one INAF Researcher is also part of the PhD committee.

4. Conclusions

The wide involvement of the younger generations and in particular of graduate and post-graduate students is required to prepare tomorrow astronomers and instrument scientists that will take full advantage of E-ELT. An important goal of T-REX is the creation and the formation of new experts and professional profiles with extremely high specialisation. This is only possible with the existing tight interaction and integration between INAF institutes and universities (Bologna, Catania, Florence, Insubria, Padua for T-REX).

A total of 4 PhD Grants were supported by the T-REX Project: the students, Mauro Patti from Bologna, Matteo Genoni from Insubria, Sara Faggi and Mirko Curti from Firenze presented their activities at the meeting in Sesto di Pusteria and more details on their contributions can be read in this volume.