Haus der Astronomie

INAF - Arcetri

Heidelberg 2013 **Padova 2014** **Jena 2015** **Firenze 2016**

Bi-national Heraeus Teacher Training Seminars

Astronomy from Four Perspectives

Supported by the Wilhelm and Else Heraeus Foundation

Organised by

Joacob Staude, Olaf Fischer, Matias Bartelmann (Heidelberg)
Piero Rafanelli, Antonio Saggion (Padova)
Karl-Heinz Lotze, Bernd Bruegmann (Jena)
Francesco Palla, Alessandro Marconi (Firenze)

The program consists of a cyclical series of training seminars for high-school teachers and teacher students in astronomy and physics, which is frontier crossing in several respects. It includes conventional elements, but in addition it leads to a horizontal exchange between participants from different countries and cultural areas, and to a vertical exchange between participants in different phases of their teacher education or professional life. All participants are exposed to precious experiences and a broadened view on their tasks in practical school teaching and academic education.

Motivation and Objectives

A decisive precondition for dedicated work is the proper attitude towards it. While this is commonplace, it is forgotten all too often that even dedication is generally transient. To strengthen the dedication of teachers for their profession, we believe that training seminars with a long-term perspective will be useful that profit from the local spirit of important places for astronomy and from the authenticity of researchers, that allow a change of perspective on the organisation and implementation of science in schools (across places and countries) and that demand stimulating communication across cultural and linguistic barriers.

To this end, we propose the training seminar series ***"Astronomy from four perspectives"***. The seminars are aimed at teacher students, teachers on probation and teachers selected at each of the four nodes of our network – Heidelberg, Padua, Jena, and Florence – and in the "zones of attraction" of these Universities. Within a cycle of four years, participants will experience for seven days each year a scientifically lively place of astronomical research that is also important for the history of science. The first seminar will take place in Heidelberg during the summer of 2013.

Why Heidelberg, Padua, Jena and Florence?

Beyond long-term professional connections between the initiators of the proposed project, the following arguments speak in favour of basing it just on these four nodes:

1. All four nodes are hotspots of actual astronomical research, e.g. in Cosmology, Gravitational Wave Astronomy, Evolution of Galaxies, Active Galaxies, Formation of Stars and Planets, Exoplanet Search, with many collaborations between their institutes and research groups in an international context. The same is true for their engagement at the forefront of instrumental development, e.g. for the Large Binocular Telescope (LBT), of which Germany and Italy have an equal share of 25 percent each.

2. All four nodes look back at a long and glorious history of astronomical research. From Galileo in Padua and Florence to Kirchhoff, Bunsen, Max Wolf in Heidelberg, and to Abbe and Zeiss in Jena, history of modern physics, astronomy and instrumental development has shaped all four townscapes. Since – as it is well known – learning science through the history of science is always essential, basing our proposed project on these four specific nodes appears to be totally natural.

3. All four nodes are strongly engaged in the education of high-school teachers in astronomy and physics and in public outreach.

Participants and their selection

About sixty participants will attend the proposed training seminars, with each node getting an equal share of 15 participants for each seminar. These 15 positions will be chosen among teacher students and teachers following approximately the following scheme: 6-7 teachers at different levels of experience, which may include teachers on probation, 6-7 teacher students, and 2 professors. Participants should preferentially be chosen from the four nodes and their surroundings, mainly to facilitate their participation in the preparatory courses and seminars.

Students and school teachers will be invited each year to attend the training seminars either on the basis of their outstanding and successful engagement during their university education – present or past –, or on the basis of their high level of interest in participating in extra-curricular activities within projects like “Science to Schools!”, “The Sky as a Laboratory”, or other teacher training seminars. Since the Heraeus training seminars will be held in English, appropriate command of English will be expected.

As for the university students, it is important to stress that a large fraction of the annual enrolment of new physics students is strongly motivated by their interest in astronomy and related topics. Since a high degree of involvement in preparing, carrying out and reworking the seminars is expected, students will receive credit points for their successful participation.

Horizontal exchange

The traditions of teachers' education in Italy and Germany differ substantially. While in Germany physics education attempts to combine an experimental foundation with theoretical concepts, the focus in Italy rests on theoretical explanation. A large fraction of physics teachers at Italian high schools has gained experience in research. In comparison, German teachers typically have received a broader training in two major school subjects and had a more pronounced teaching-oriented component in their education.

We see these differences as a highly welcome potential, which we shall harness. Teachers will be encouraged to engage in the seminars according to their respective strengths. We wish to strengthen the self-conception of teachers as researchers with the particular assignment to carry science into schools in an educationally skillful way. Getting acquainted with different teaching traditions will inspire the further development of lessons.

Vertical exchange

Among the participants will be professors of physics and astronomy and their student teachers, as well as fully trained, practicing teachers and possibly teachers on probation from all four locations and their surroundings. Bringing together participants of different age and different levels of practical experience, linking contemporary research to its local history, repeating the seminars yearly and varying the location cyclically will jointly advance a lively, sustainable collaboration, which will surmount linguistic and cultural barriers and will quickly develop a tradition of its own.

Structure of the proposed Heraeus Seminars

The seven-day programme consists of one part dominated by the subject of research and a second part dominated by teaching and education. Both sections of the programme will be separated by a one-day excursion for recreation and relaxed communication between the seminar participants.

The two halves of the programme have two well-defined and different purposes. In the first half, the participants will be exposed to an area of current research. For this purpose, brief introductory lectures will be held by researchers while most of the material will be developed in guided discussions and workshops by the participants. The essential goal of this first half will be enabling the participants to understand central questions of the area of research studied and to arrive at quantitative results themselves.

In the second half, the focus will be on enabling the participants to explain to their pupils the subject area, its central questions and some of its quantitative conclusions. The majority of the educational material needed will be supplied, but the participants will also be encouraged to develop material on their own.

Besides testing and developing material for schools, a further purpose of the seminars will be to collect ideas and identify needs for the training of teacher students at the universities. An example could be the design of a course on relativistic astrophysics for teacher students.

The following types of classes are foreseen:

– Plenary talks, during which researchers and university teachers convey first-hand knowledge;

– Plenary discussions, during which essential contents will be developed under the guidance of researchers;

– Discussions on individual subjects in parallel working groups, for example on three well-defined problems in three working groups under the guidance of researchers;

– Plenary presentations by the working groups, in which problems and their solutions will be presented by members of the working groups;

– Development and test of teaching materials; for example, four workshops will be offered in which different teaching materials can be developed and tested under the guidance of teachers;

– Plenary presentations of the results achieved by the workshops, including the presentation of the test results from an educational perspective;

– Plenary discussions on particular, unanticipated projects and ideas;

– Possibly plenary classes on historical developments;

Selection of Subject Areas

Heidelberg 2013 - Cosmology

Cosmology attracts the interest of many students and pupils, but is rarely taught because its origin in General Relativity seems to push it out of reach. Nonetheless, basic concepts of cosmology, and some of its far-reaching results, can be derived from Newtonian physics. The purpose of this project is to explain why there are good reasons that Newtonian physics reaches a long way into cosmology, to derive some fundamental statements on cosmology, and to understand from where our knowledge on cosmological parameters is inferred. The contents and structure of this project is devised such, that simple yet fundamental results can be obtained by the participants themselves with little guidance from the background.

The course would begin with a plenary discussion on the foundations of Newtonian gravity, on the symmetry assumptions in cosmology, and how the combination of both implies that a rich collection of cosmological results can be obtained from Newtonian physics alone.

Next, the concepts of space-time curvature, spatial curvature and their difference will be introduced with simple examples. It will be explained why this leads to ambiguities in the definition of distances. Different distance measures will be introduced and explained. The thermal history of the Universe will be the next important step. It will be discussed under which conditions

a temperature can be assigned to the Universe as a whole in the first place, what such a temperature means, when different particle species freeze out and why, and what happens to their distribution thereafter.

Structure formation will be discussed next. Possible solutions to this evolution equation will then be derived. It will be shown, why the result implies, together with the temperature fluctuations in the CMB, that cosmic structures must be dominated gravitationally by Dark Matter. Type-Ia supernovae can now easily be studied. Distances and their dependence on cosmology were introduced before. The luminosity distance is the only essential ingredient required for understanding the necessity for cosmic acceleration from supernova data. The analysis can be repeated by the participants themselves with straightforward means.

Most of the materials listed here can be developed by the participants in working groups. Once the participants will have experienced what far-reaching results can be achieved with advanced high-school physics, they will devote the second half of the week to testing available teaching material themselves and to develop new material, if possible.

Padova 2014 - Space, Time and Gravity: The case of Active Galactic Nuclei

We propose to devote all four-yearly Summer Schools in Padua to an especially wide field of fundamental physics, namely **Space, Time and Gravity**, whose concepts can be applied to almost all aspects and problems of modern Astronomy and Astrophysics., although we will focus on the case of **Active Galactic Nuclei (AGN)**

AGN and their close relatives, quasars and other types of quasi-stellar objects are a field of research, which has grown explosively in the last 40 years. Almost all we know about them came from the study of their spectra, and especially their emission-line spectra, very similar but not identical with those of gaseous nebulae. The study of all these objects has paralleled the study of gaseous nebulae. For this reason we introduce in the last section of our programme the basics of spectroscopy of gaseous nebulae before discussing the interpretation of the observed features of AGN.

(1) Teachers have defined a course for secondary school students on the introductory topics of the syllabus; (2) teacher students have communicated to the university teachers the results of their study, formulated in an educational way at the university level; (3) teachers have available a starting point for translating the concepts that have been explained by the work of the university students into a language accessible to secondary-school pupils; (4) all teachers and students have acquired the conceptual and practical skills necessary to face an astrophysical problem concerning the nature of AGN.

Jena 2015 - Gravitational Wave Astronomy

In 2015 it will be 100 years that Albert Einstein completed and published his Theory of General Relativity. The existence of gravitational waves belongs to the predictions of this theory. This forthcoming **“Einstein Year”** suggests to host the seminar of 2015 at the University of Jena and to dedicate it to gravitational wave astronomy.

The Teaching approach consists of a treatment of gravitational waves is based on General Relativity. Since it is unrealistic to assume that the participants will be familiar with this theory or

that it could be thoroughly developed during the seminar, an approach to gravitational waves needs to be and can be found that requires only limited mathematical tools without avoiding them, and that strongly emphasizes the physical concepts. Moreover, even education in Newtonian gravity is effectively non-existent at schools. It is thus necessary to elaborate on the free fall, the state of weightlessness and in particular the phenomenon of tides on the basis of Newtonian gravity. Thought experiments on freely falling elevators are a proven instrument.

For understanding *what gravitational waves are* and why they are so comparatively weak, a comparison between electro- and gravitostatics may help, followed by a comparison between electromagnetic and gravitational waves. The *sources of gravitational waves* will follow, whereupon dimensional analysis can fruitfully be used to estimate their radiative power. T

he major fraction of the discussions will focus on the *empirical verification of gravitational waves* by means of modern terrestrial (LIGO, VIRGO, GEO 600) and space-borne (eLISA/NGO, previously LISA) laser interferometers. In this context, the theory of mechanic oscillations (damping of oscillations, quality factor) plays a major rôle, which can be supported by simple experiments.

Florence 2016 – Origins: the Birth of Stars and Planetary Systems

The Teaching activities will focus on the *Birth of Stars and Planetary Systems*, i.e. on how interstellar gas and dust turn into stars and planets. The complex of processes known as star and planet formation has occurred innumerable times in the remote past. The Big Bang, after all, did not produce a Universe full of stars but of diffuse gas. Anyone studying this problem is aided immeasurably by the fact that star formation is also occurring now, and in regions close enough for the transformation to be examined in great detail. This effort is pursued both, observationally and theoretically.

As Galileo first pointed out in the *Sidereus Nuncius*, planets and stars are the main constituents of the visible universe. He deliberately put the description of the planets of the solar system and that of constellations and nebulae side by side, which reflects the same physical processes occurring at birth: stars form from the accretion of interstellar matter that is concentrated in dense circum-stellar disks that also produce an accompanying cohort of planets. This picture has been directly confirmed in the last twenty years or so by the discovery of extra-solar planetary systems orbiting around evolved stars of various types, both single and in binary systems. Not only does the predicted number of planets existing in our Galaxy (and, *in extenso*, in all galaxies) exceed by far any previous estimate, but the properties of the extra-solar systems identified so far testifies to the complexity and variety of the process of which our solar system is but one example. These topics are very attractive both to the students, since they form one of the main research areas in astrophysics, and to teachers, who find this material still rarely covered in the current curricula despite its overall importance.

The programme will include an extended visit to the Galileian sites in Florence: a tour to the *Galileo Museum* with its rich collection of scientific instruments owned by Galileo, including the original telescope and lenses; the *National Library*, with its collection of Galileo's manuscripts and books; the *Church of S. Croce* where Galileo is buried along with his daughter Suor Maria Celeste; the *Villa Il Gioiello* where Galileo lived between 1632 and 1642. The seminar participants can also observe at night using a replica of the original *cannocchiale* with clones of the original lenses, built by the Arcetri Observatory and equipped with a digital camera to take images.