



Guidelines for Graduate Studies by Research Scholars

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1 Introduction

The Graduate Programme at NCRA, Pune, involves both course work and research work in the areas of observational and theoretical astrophysics, with an emphasis on radio astronomy. There are also courses on basic physics and mathematical methods relevant for astronomy and astrophysics.

The normal duration of the Programme, including the doctoral research, is five years for Regular Ph.D. students and six years for Integrated Ph.D. students, within which the student is expected to submit a thesis for a Ph.D. degree to the Tata Institute of Fundamental Research (TIFR), a deemed University, or any other University/Institution with whom NCRA has a formal arrangement. Details regarding the requirements of the University/Institution can be obtained from the Faculty Office at NCRA.

The Graduate Programme is monitored by the Academic Affairs Committee (AAC). The Chairperson of this committee has the overall responsibility for the Programme. The academic activities of all Ph.D. students are monitored by the AAC, who will work in co-ordination with the Ph.D. supervisor and the Ph.D. Advisory Committee which is set up for each student. The student's supervisor will be a member of his/her Ph.D. Advisory Committee, along with one member of the AAC, and one member of the NCRA faculty.

Policies and guidelines concerning various aspects of the Graduate Programme are described below. Further information and recent updates are available on the NCRA (<http://www.ncra.tifr.res.in>) and TIFR (<http://www.tifr.res.in>) web pages.

2 Admission to the Graduate Programme

2.1 Normal Procedure

The normal procedure for admission to the Graduate Programme is via the JEST (Joint Entrance Screening Test), INAT (IUCAA-NCRA Admission Test) and TIFR written tests. These are announced through advertisements placed in several national newspapers and the NCRA web page, as well as notifications sent to different educational/research institutions. Based on their performance in the written test and assessment of their academic abilities, candidates are invited for interviews. Candidates short-listed via JEST and INAT are interviewed at Pune. These interviews may be conducted jointly with the Inter-University Centre for Astronomy and Astrophysics (IUCAA). Candidates who clear these interviews are selected to join NCRA's Graduate Programme as Research Scholars, in either the Regular Ph.D. or Int-Ph.D. programmes (see below). Those short-listed via the TIFR written test are interviewed at TIFR (Mumbai). Students who take the TIFR exam and interview, and opt to join NCRA from the time of induction, will join the IUCAA-NCRA Graduate School at the outset. For students who have carried out their Graduate School work at TIFR, the norms for transfer to NCRA at the end of the Graduate School are available on the web page of the Subject Board of Physics, TIFR.

Research Scholars may also be pre-selected from the Visiting Students' Research Programme (VSRP), conducted each summer at NCRA. Students may apply for this programme directly to NCRA or via TIFR (Mumbai). Students who are entering the final year of the M.Sc./B.E./B.Tech./B.Sc. courses or entering either the penultimate or the final year of an integrated M.Sc. course are eligible for the VSRP. Selected students spend about two months during the summer working on a project at NCRA. Based on their performance during the VSRP, which includes a project seminar and interviews, students may be pre-selected to join NCRA's Graduate Programme after they satisfactorily complete their M.Sc./Int.M.Sc./B.E./B.Tech./B.Sc. course.

Students with an M.Sc./Int-M.Sc. degree in Physics/Mathematics/Electronics/Astronomy would be admitted to the Ph.D. programme as "Regular Ph.D." students, and would directly attend the courses of the IUCAA-NCRA Graduate School. Conversely, students with a B.Sc. degree in Physics/Mathematics/Electronics/Astronomy or a B.E./B.Tech. degree in any branch would be admitted to the Integrated Ph.D. ("Int-Ph.D.") programme and would undergo one year of M.Sc.-level courses conducted jointly with either the Indian Institute of Science Education Research (IISER), Pune, or the Department of Physics, University of Pune, before joining the IUCAA-NCRA Graduate School. Further details of the Int-PhD programme are given on the webpage <http://www.ncra.tifr.res.in/>.

Thus, a Research Scholar in NCRA will belong to one of the following two categories, based on his/her qualifications and background at the time of entering the Programme:

- Regular Ph.D. student: Students with an M.Sc. degree in Physics, Electronics, Astronomy or Applied Mathematics, or with an M.E./M.Tech. degree in any branch would be in this category.
- Integrated Ph.D. (Int-Ph.D.) student: Students with a B.Sc. degree in Physics, Electronics, Astronomy or Applied Mathematics or a B.E./B.Tech. degree in any branch would be in this category.

The category of a student who does not clearly belong to one of the above categories will be determined by the NCRA Faculty.

2.2 Exceptional Case for Research Scholars: Applicants from Abroad

An exception to the requirements described above for admission of Research Scholars to the NCRA Graduate Programme may be made for applicants who are not in India and are therefore unable to appear for the standard tests and interviews. This procedure must be used sparingly and only in outstanding cases. Details of this procedure are described in Appendix 1.

3 Graduate School Courses

3.1 Enrollment

Research Scholars are normally required to join the Institute on or before August 1 every year.

The Int-PhD students would undergo one year of course work at IISER, Pune, or at the Department of Physics, University of Pune, followed by a short summer project and then another year of courses in the IUCAA-NCRA Graduate School. These students would also have to carry out research projects in the first half of their third year. Conversely, the Regular Ph.D. students would do one year of courses in the IUCAA-NCRA Graduate School, followed by research projects in the first half of their second year.

Research Scholars are allowed to register for a Ph.D. with the TIFR (Mumbai) Deemed University once they successfully clear all requirements of the NCRA Graduate School concerning the courses and the research projects. These requirements are detailed in Section 5.

3.2 Courses for Integrated Ph.D. Students

The Int-PhD students will undergo course work at IISER, Pune, or at the Department of Physics, University of Pune, during their first year. This will be followed by a short summer project in NCRA. In their second year, they will attend the courses offered in the IUCAA-NCRA Graduate School. Students are normally expected to clear all the courses at the first attempt. However, in case the student fails in one or more courses at the first attempt, he/she will be given a second chance to clear the courses in the subsequent year(s). The AAC would guide the student(s) regarding this, whenever a need would arise. The detailed evaluation procedure and performance requirements are given in the next section.

In the first academic year (August to May), the student has to take ten M.Sc.-level courses conducted at IISER, Pune, or at the Department of Physics, Pune University. The list of courses is given in Table 1.

The Int-PhD students will carry out a short (6-week) project, either in the Radio Physics Laboratory (RPL), NCRA, or with an NCRA faculty member, during the summer of their first year. This project will have 4 credits.

In their second and third years, the Int-PhD students will have the same course and project requirements as Regular Ph.D. students in their first and second years, with the same credit structure. In essence, the Int-PhD students will attend the courses of the IUCAA-NCRA graduate school in their second year and will carry out two 3-month research projects (described in Section 3.4) in the first half of their third year. Table 1 summarizes the courses, teaching hours and credit structure for Int-PhD students for all three years, while the evaluation structure and performance requirements are set out in Section 4.

| Table 1: Course Outline for Integrated Ph.D. Students | | | |
|---|---|----------------|---------|
| S1 | Course | Teaching hours | Credits |
| Semester - I: Early August to early December (IISER/Pune University)¹ | | | |
| 01 | Mathematical Methods in Physics | ~ 40 | 4 |
| 02 | Classical Mechanics | ~ 40 | 4 |
| 03 | Quantum Mechanics I | ~ 40 | 4 |
| 04 | Electronics | ~ 40 | 3 |
| 05 | General Laboratory I / Computer Laboratory | ~ 40 | 3 |
| Semester - II: Early January to early May (IISER/Pune University)¹ | | | |
| 06 | Quantum Mechanics II | ~ 40 | 4 |
| 07 | Statistical Mechanics | ~ 40 | 4 |
| 08 | Electrodynamics I | ~ 40 | 4 |
| 09 | Atoms, Molecules and Solids | ~ 40 | 3 |
| 10 | Computer Laboratory / General Laboratory I | ~ 40 | 3 |
| Summer Project: Mid-May to mid-July (NCRA) | | | |
| 11 | RPL or Experimental/Reading Project | – | 4 |
| Semester - III, Term - I: Early August to end-September (IUCAA/NCRA) | | | |
| 12 | Methods of Mathematical Physics I | 21 | 3 |
| 13 | Introduction to Astronomy and Astrophysics I | 14 | 2 |
| 14 | Electrodynamics and Radiative Processes I | 14 | 2 |
| 15 | Quantum and Statistical Mechanics I | 14 | 2 |
| Semester III, Term II: Mid-October to mid-December (IUCAA/NCRA) | | | |
| 16 | Methods of Mathematical Physics II | 14 | 3 |
| 17 | Introduction to Astronomy and Astrophysics II | 14 | 2 |
| 18 | Electrodynamics and Radiative Processes II | 14 | 2 |
| 19 | Quantum and Statistical Mechanics II | 14 | 2 |
| Semester - IV, Term - I: Early January to mid-March (IUCAA/NCRA) | | | |
| 20 | Astronomical Techniques I | 14 | 3 |
| 21 | Galaxies : Structure, Dynamics and Evolution | 21 | 3 |
| 22 | Extragalactic Astronomy I | 21 | 3 |
| Semester - IV, Term - II: Mid-March to mid-May (IUCAA/NCRA) | | | |
| 23 | Astronomical Techniques II | 14 | 3 |
| 24 | Interstellar Medium | 14 | 3 |
| 25 | Extragalactic Astronomy II | 14 | 3 |
| Semester V, Term I: Mid-June to mid-September (NCRA) | | | |
| 26 | Research Project I | – | 12 |
| Semester V, Term II: Early-October to end-December (NCRA) | | | |
| 27 | Research Project II | – | 12 |
| | Total Credits | | 100 |

¹These courses are listed according to the curriculum followed at the Pune University, the exact listing of courses may vary at IISER.

3.3 Courses for Regular Ph.D. Students

The Regular Ph.D. students are required to attend all the courses offered in the IUCAA-NCRA Graduate School in their first year. During the Graduate School, Research Scholars are taught a set of basic courses in Physics and Mathematics and are also introduced to courses in Astronomy and Astrophysics. The Graduate School structure is given in Table 2, with the number of teaching hours and the credits assigned to each course also shown. Note that the ordering of the courses in the Graduate School may have to be altered (with approval from the Dean NF) in some unavoidable circumstances. The students will be notified well in advance in case such

a situation arises. A course may be given as a reading course if there are only one or two students taking the course. Students are normally expected to clear all the courses in the first year. However, in case a student fails in one or more courses in the first year, he/she will be given a second chance to clear the courses in the second year. The detailed evaluation procedure and performance requirements are given in Section 4.

| Table 2: Course Outline for Regular Ph.D. Students | | | |
|---|---|----------------|-----------|
| S1 | Course | Teaching hours | Credits |
| Semester I, Term I: Early August to end-September | | | |
| 01 | Methods of Mathematical Physics I | 21 | 3 |
| 02 | Introduction to Astronomy and Astrophysics I | 14 | 2 |
| 03 | Electrodynamics and Radiative Processes I | 14 | 2 |
| 04 | Quantum and Statistical Mechanics I | 14 | 2 |
| Semester I, Term II: Mid-October to mid-December | | | |
| 05 | Methods of Mathematical Physics II | 14 | 3 |
| 06 | Introduction to Astronomy and Astrophysics II | 14 | 2 |
| 07 | Electrodynamics and Radiative Processes II | 14 | 2 |
| 08 | Quantum and Statistical Mechanics II | 14 | 2 |
| Semester II, Term I: Early January to mid-March | | | |
| 09 | Astronomical Techniques I | 14 | 3 |
| 10 | Galaxies : Structure, Dynamics and Evolution | 21 | 3 |
| 11 | Extragalactic Astronomy I | 21 | 3 |
| Semester II, Term II: Mid-March to mid-May | | | |
| 12 | Astronomical Techniques II | 14 | 3 |
| 13 | Interstellar Medium | 14 | 3 |
| 14 | Extragalactic Astronomy II | 14 | 3 |
| Semester III, Term I: Mid-June to mid-September | | | |
| 15 | Research Project I | – | 12 |
| Semester III, Term II: Early-October to end-December | | | |
| 16 | Research Project II | – | 12 |
| | Total Credits | | 60 |

3.4 Research Projects

After the completing the courses, each student will have to carry out two 3-month research projects. The Regular Ph.D. students would carry these out during the first half of their second year in NCRA, while the Int-PhD students would do these during the first half of their third year.

One of these projects must be based on the observational or instrumentation facilities operated by NCRA (i.e. the Giant Metrewave Radio Telescope, the Ooty Radio Telescope, the 15-m telescope, new hardware, or facilities in the Radio Physics Laboratory). The two projects must be carried out with different members of the NCRA Faculty. Students will have to give a seminar at the end of each project and submit a formal report; they will be graded on the basis of each seminar as well as their performance during the project.

Students are encouraged to approach faculty members for prospective projects during Semester-II (for Regular Ph.D. students) and Semester-IV (for Int-PhD students). A faculty member who intends to provide a project must give a brief description of the scope and contents of the project to the AAC as early as possible, and definitely by May 21. The students will be provided a list of projects and abstracts for both projects by June 1, and will have to choose both projects within a week's time. The first project will be from June 15 to September 15, and the seminar on this project must be completed, and the report submitted, by September 30. The second project will run from October 1 to December 31, with the seminar to be completed, and the reported submitted, by January 15.

In case the student fails in one of the projects (but clears the other one), he/she will be allowed to carry

out an additional 3-month project to satisfy the Graduate School requirements. This extra project may not be a continuation of either of the earlier two projects and will run from January 16 to April 15; the seminar must be completed by April 30.

The detailed evaluation procedures and passing criteria for the two projects are given in Section 4.

3.5 Exemption from Attending the Lectures

Normally, no graduate student will be exempted from completing the course requirements. However, if a Regular Ph.D. student feels that he/she is thoroughly familiar with the material in a particular course in the IUCAA-NCRA Graduate School, he/she may request the lecturer to exempt him/her from attending the lectures and to evaluate him/her directly. It is up to the lecturer to decide whether such an exemption should be granted. No such exemption will be granted to Int-PhD students under normal circumstances.

3.6 Student Feedback

At the end of each semester in the IUCAA-NCRA Graduate School, students will be given an opportunity to evaluate the courses and course instructors in a prescribed form. This evaluation will be sent to the Directors of IUCAA and NCRA and will be treated as confidential.

4 Evaluation in the Graduate School

4.1 Courses

The performance of the students in the courses will be evaluated on the basis of a combination of written test(s), home assignments, classroom discussions and/or seminars. For every course, the instructor would give each student a numerical grade between 0% and 100%, depending on his/her performance in the course. If a student gets 40% or less in a course, he/she is deemed to have failed the course. The student will be allowed to repeat, and attempt to clear, the course in the next year provided that he/she has done sufficiently well in the other courses (see below).

4.2 Research Projects

For the research projects, the student will be required to give a seminar and submit a project report within the stipulated deadlines. The deadlines are September 30 for Project I, and January 15 for Project II. In case a student needs to carry out an additional third project, the deadline for its seminar and project report is April 30. If the project seminar and report are not submitted by the stipulated date, the student will be deemed to have failed the course. The project work will also be reviewed by a committee consisting of the guide and the AAC; this committee will give the final grade on the project which is a number between 0% and 100%. The student must secure more than 40% in order to pass a particular project. In addition, the average grade over both projects must be more than 60%.

4.3 Cumulative Performance Index (CPI)

The marks obtained in the courses and research projects would be used to calculate a Cumulative Performance Index (CPI) as follows:

$$\text{CPI} = \frac{\sum_i \text{credits for course } i \times \text{percentage marks obtained in course } i}{\sum_i \text{credits for course } i}$$

where the sum over i runs over all courses under consideration.

5 Graduate School Performance Requirements

A student must satisfy the following conditions in order to satisfactorily complete the requirements of the NCRA Graduate School. If a student fails to satisfy the above criteria at the end of the course work (i.e., at the end of two years for Regular Ph.D. students and at the end of three years for Int-PhD students), he/she would be asked to leave NCRA.

- The student should pass all courses, i.e., he/she should score more than 40% in all courses (both courses and research projects), within the period of his/her course work (two years for Regular Ph.D. students and three years for Int-PhD students).
- The student must get a aggregate CPI of at least 60% over all courses.
- The student must get a CPI of at least 60% in the two research projects, i.e. an average grade of 60% in the research projects.

Students would be required to leave NCRA under the following circumstances:

1. If a student fails to meet the three performance criteria listed above at the end of the Graduate School, he/she would be required to leave NCRA.
2. If a student fails to achieve an aggregate CPI of 60% at the end of each semester (whether or not he/she has failed some courses), he/she would be required to leave NCRA.
3. If a student fails in more than three courses (i.e. in four or more courses) at any point in the course work, he/she would be required to leave NCRA.
4. If a student obtains a grade of 40% or less in both of the initial 3-month research projects, he/she would be required to leave NCRA.

The following safety nets have been provided for students failing to clear the requirements of the Graduate School at the first attempt:

- If a Regular Ph.D. student has a CPI of at least 60% at the end of each semester, but has failed in one or more, but fewer than four, courses, he/she will be given another chance to clear these courses in the second year. At the end of the second year, the student should satisfy all the three criteria listed above, otherwise he/she will have to leave the institute.
- Int-PhD students have to maintain a minimum CPI of at least 60% at the end of each semester. A student may fail at most three courses during the entire two year duration of the course work. Students who have failed in four or more courses will have to leave the Graduate School. Students who have failed one or more courses must clear these courses by the end of their third year in the programme. At the end of the third year, a student should satisfy all the three criteria listed above; if not, he/she would have to leave the institute.
- In case a student scores 40% or less in one of the research projects or if his/her CPI on the two projects is lower than 60%, he/she would be allowed to carry out an additional 3-month project to satisfy the Graduate School requirements. This extra project may not be a continuation of either of the earlier two projects and will run from January 16 to April 15; the seminar must be completed and the project report submitted by April 30. If a student is required to carry out a third project, the CPI on the research projects will be computed based on the two highest grades obtained out of the three projects.

6 Requirements for Ph.D. Registration

Research Scholars may register for a Ph.D. after successful completion of their Graduate School (i.e. courses and the two research projects). Note that the stipends of Regular Ph.D. and Int-PhD students are raised after two and three years, respectively, provided their Graduate School studies have been completed satisfactorily, their progress is assessed to be satisfactory, and they have registered for their Ph.D.

6.1 M.Sc. Degree for B.Sc./B.E./B.Tech. students

Students with a B.Sc., B.E. or a B.Tech. degree should register for an M.Sc. in Physics immediately after joining NCRA as Research Scholars. The NCRA Graduate School course work is considered by the TIFR Deemed University to be equivalent to the course requirements of an M.Sc. degree. B.E./B.Tech. students who are enrolled as Regular Ph.D. students, will also have to submit an M.Sc. thesis; this would usually be based on the reports of the two research projects carried out as part of the Graduate School course work. B.Sc./B.E./B.Tech. students would typically be granted their M.Sc. degrees after clearing all requirements (including courses and research projects) of the NCRA Graduate School.

6.2 Thesis Advisor Selection for Research Scholars

Registration for a Ph.D. requires the identification of a thesis supervisor (an academic member of NCRA with a rank of Fellow or higher) for the candidate. Keeping this in mind, students are encouraged to get acquainted with the research areas being pursued at NCRA as early as possible and to interact personally with the Faculty members to find out their research interests and availability as guides. Finding an advisor who is willing to supervise the work of a student is solely the responsibility of the student. However, he/she will be advised and assisted by the AAC whenever required.

Ideally, the student should have identified a supervisor by the end of the Graduate School (i.e., by the end of the second research project). In case a student fails to identify an advisor by then, he/she will be given time till the end of the academic year (which would correspond to the end of the second year in NCRA for Regular Ph.D. students and the end of the third year for Int-PhD students). If the student is still unable to find an advisor at this time, his/her Research Scholarship will be terminated.

The name of the supervisor and the broad area of research must be provided to the NCRA Faculty Office before a student is allowed to register for a Ph.D.. In addition, a written outline of the Ph.D. project, signed by both the supervisor and the student, should be submitted to the Faculty Office.

6.3 Ph.D. Advisory Committee (PAC)

Each Ph.D. student will have a Ph.D. Advisory Committee (PAC), consisting of at least three faculty members, to monitor his/her progress till the completion of the Ph.D.. The PAC will consist of the student's supervisor, a member of the AAC and an additional NCRA Faculty member. The PAC will also monitor the performance of the student at least once every year, typically in May/June, and make recommendations concerning the renewal or termination of the student's Research Scholarship.

7 Requirements and Procedures for a Ph.D. Degree

7.1 Monitoring the Progress of a Student

The appointment of a Research Scholar is for one year at a time, and it is extended each year subject to satisfactory performance. The progress of all Research Scholars will be reviewed by their respective PACs every year, typically in May/June. The review is based on (1) a seminar given by the student where he/she describes the work done during the preceding year, and (2) a discussion with the PAC on the work done and the student's plans for the future. Based on this discussion and the seminar grades, the PAC will recommend extension

(for a year) or termination of the student's Research Scholarship. The PAC may also recommend a mid-term review, if closer monitoring is felt to be necessary. The PAC or the supervisor should bring any problems in the student's progress (either apparent or envisaged) to the attention of the AAC as early as possible. Similarly, students are encouraged to talk to members of their PAC (or members of the AAC) to sort out any academic problems, including problems with their supervisor. The students are especially advised to not wait until the annual review to take up such issues, but to bring them to the notice of the PAC/AAC as early as possible.

7.2 Duration of Ph.D. Programme

A Regular Ph.D. student is expected to submit his/her Ph.D. thesis to TIFR (Mumbai) or the University at which he/she is registered within five years of the date of joining the NCRA Ph.D. Programme (i.e. including the Graduate School). The corresponding limit for Int-PhD students is six years. Research Scholars who fail to complete their work within these periods will have to request an extension. In such cases, the Ph.D. Advisory Committee should refer the matter to the NCRA Faculty, along with a justification for the extension. The Faculty will review the case and recommend an extension, if felt appropriate. In general, such extensions should be granted for less than six months at a time and should not exceed a total of one year. The total duration of the thesis is expected to be no more than six years for Regular Ph.D. students and seven years for Int-PhD students. Extensions beyond these limits will be allowed only in exceptional cases, based on a written application from the advisor, which will be discussed in the NCRA Faculty.

7.3 Thesis Seminar

Before submitting the Ph.D. thesis, every candidate is required to give a seminar on the work on which the thesis is based, before submission of the thesis synopsis. The NCRA Faculty Office will make arrangements for the thesis seminar, including the setting up of an evaluation committee; this will be done in consultation with the chairperson of the AAC. The synopsis will only be submitted to the University after the seminar has been delivered. The grades given by members of the evaluation committee will be kept in the file of the candidate. If the average grade of the committee is lower than 60%, the thesis will not be forwarded to the University. The committee's recommendations should be taken into account and the synopsis/thesis revised accordingly before submission.

7.4 Visiting Fellowship After Submission of Thesis

A Regular Ph.D. student who has submitted his/her thesis within a maximum period of six years (within seven years for Int-PhD students) will, on application, be offered a short-term Visiting Fellowship (typically for 6 months) at NCRA to allow completion of the thesis evaluation formalities as well as ongoing research projects. Students exceeding this maximum period are unlikely to be offered a Visiting Fellowship without a clear justification and a strong recommendation from the Ph.D. Advisory Committee. Each such case will be discussed in detail in the NCRA Faculty. Regular Ph.D. students requiring seven years (eight years for Int-PhD students) or more to complete a thesis will not be offered such a Visiting Fellowship.

8 Some General Issues

8.1 Support Activities

All Research Scholars are expected to take part in support activities, especially in the observatory, to enrich their experience and learning and also to contribute to the Centre.

8.2 Seminars, Colloquia etc

Research Scholars are expected to participate in academic activities, such as seminars, colloquia, informal discussion meetings, etc. Every Research Scholar is required to give one additional talk, apart from the talk during the annual review of their fellowship, during each academic year. Research Scholars are also encouraged to give additional seminars, both at NCRA and at other institutes.

8.3 Contingency Grant

Both Regular Ph.D. and Int-PhD students will be provided an annual contingency grant (currently Rs. 20,000/- per year), tenable for 5 years for Regular Ph.D. students and 6 years for Int-PhD students. The items covered by the grant are scientific and reference books (including dictionaries and encyclopedias), science journal subscriptions, memberships of professional societies, laptops, electronic storage media (e.g. USB memory devices, hard drives, RAM, etc), software items, telescopes, Ph.D. Registration/Thesis fees. The purchase of other items required for research purposes may also be permitted, based on the recommendations of the guide or the Academic Affairs Committee.

The contingency grant is maintained on the basis of the academic year, i.e. August to July, and is non-cumulative. However, if a specific item (e.g. a laptop) costs more than the total annual contingency grant, students may be permitted, based on the recommendations of the guide or the Academic Affairs Committee, to combine the grants from two or more years in order to purchase the item.

8.4 Leave of Absence for Research Scholars in the First Year

During the courses of the Graduate Programme (either in IISER or in the IUCAA-NCRA Graduate School), students will not be allowed to take leave from the institute except in circumstances such as illness or emergencies. In any event, absence from the Programme during the first year will be permitted only with the consent of the chairperson of the AAC.

Students attending the courses are not generally expected to go out of station to attend scientific conferences or workshops, or to go on deputation. An exception to this norm must be recommended by the AAC, and then discussed and approved by the NCRA Faculty.

Research Scholars are not permitted to go on vacation while their courses are in progress. Vacation can be taken only during the breaks in the Graduate School. Once the courses are over, students are entitled to seventy days of leave in a year, provided the leave is taken during the vacation period (October 1 to October 31, December 16 to January 14, March 1 to June 30). Further details of leave can be obtained from the Faculty Office. All requests for leave must be approved in advance by the Ph.D. supervisor or the chairperson of the AAC.

8.5 National Eligibility Test (NET)

It is strongly recommended that NCRA Research Scholars pass the CSIR/UGC National Eligibility Test (NET) at the earliest opportunity.

9 Students or Guides Affiliated to Other Institutions

9.1 Students working at NCRA

Students affiliated to an institution other than TIFR but desirous of working at NCRA for extended periods must have a guide and a research problem clearly identified in their parent institution. Such a collaborative effort, in which an NCRA staff member is interested in partially supervising the student, would contribute to increasing academic activities at NCRA. However, the following norms should be followed:

1. The NCRA staff member with whom the student is working, and who is responsible for the student, should be clearly identified.
2. The total duration of such visits by one student should not exceed six months in a calendar year. In exceptional circumstances, this could be extended to at most nine months.
3. The total number of such external students at NCRA at any given time should in general not exceed five.
4. Such visits should be mentioned in the NCRA Faculty meetings as an informational item. The students should also be encouraged to give a talk at the end of each visit.
5. The students are expected to be financially supported by their parent institute or their own research grants. However, efforts will be made to provide logistical support. Students from India and abroad will be treated at par.
6. Accommodation in the NCRA hostel will be provided to such students depending on availability, and following the hostel norms.

9.2 NCRA Members Guiding Students Working Elsewhere

Occasionally, an NCRA member may be requested to be the Ph.D. guide of a student who intends to carry out doctoral work at another institution. NCRA imposes no constraints on this activity, except that the thesis may not be submitted through NCRA. The doctoral research of such students will be governed entirely by the rules and regulations of his/her institution. However, the NCRA Faculty Office should be informed about such cases.

Appendix 1: Research Scholar Applications from Abroad

The procedure for Research Scholar applications from persons residing outside India who are unable to participate in the Regular selection procedure is described below;

Such candidates should write to the Dean (NCRA) or the chairperson of the AAC, either of whom may then propose the case at a meeting of the AAC. The AAC should examine such cases carefully and satisfy itself that the applicant is genuinely unable to appear for the test and interviews. In such cases, every effort should be made to interview the candidate over telephone/video conferencing/Skype if possible. The AAC should also assess the candidate's qualifications and aptitude; this assessment may be based on reference letters, publications, and any other available information.

If the AAC is convinced that the candidate should be admitted to the Graduate Programme, it should make a clear recommendation to this effect to the Director or Dean, NCRA. The AAC may also bring the matter up for discussion at the NCRA Faculty, if it finds this necessary, before making a recommendation to the Director or Dean. The recommendation must explain why the candidate is unable to undergo the normal selection procedures, and must state the academic grounds on which admission of the candidate is being recommended.

The final decision will be made by the Director or the Dean, NCRA and communicated to the applicant.

An applicant who is offered admission in this way should be aware that the normal duration of the NCRA Ph.D. programme is five years. This is important for foreign students who may have restrictions on their period of absence from their home country. The applicant should also be made aware of the fees payable to the University, the type of visa required and any other regulations that may be in force.

Candidates selected through this procedure will in all other respects be subjected to the same rules and requirements as those selected through the normal procedure.

Appendix 2: Syllabus for the IUCAA - NCRA Graduate School Courses

(a) The courses are designed so as to emphasize aspects that are directly relevant to Astronomy and Astrophysics and to avoid unnecessary repetition of material already taught in M.Sc. syllabi. While selecting students for the IUCAA/NCRA Graduate School, we try to ensure that the student is familiar with physics at the M.Sc. level, so that there is no need for routine material to be repeated in the graduate-level course.

(b) The syllabus provides enough avenues for topics which are of “local interest” to be included in the Graduate School. This is necessary so that graduate students coming out of IUCAA/NCRA not only have a comprehensive grasp of astronomy and astrophysics but are also aware of the key research areas in which these two institutions are concentrating at present.

01. Methods of Mathematical Physics I

[The emphasis will be on practical aspects of using mathematics to solve problems rather than on formal mathematical proofs. Emphasize on Green’s functions, and Fourier analysis].

Sturm-Liouville problem and its connection with special functions - Partial differential equations (inhomogeneous and homogeneous wave equations, diffusion equation, Green functions) - WKB and other approximation methods, series expansions, saddle-point, etc. - Fourier analysis.

02. Introduction to Astronomy and Astrophysics I

[All these topics will come up for detailed study later; the aim of this course will be to connect physics with astrophysics at an order-of-magnitude level and to introduce conventions and jargon of astronomy and astrophysics to a physics student].

Earth-solar system - The Sun as a star - Stellar structure and evolution - The HR diagram - Colours, magnitudes, Spectral classification - White dwarfs, neutron stars, black holes - Binaries - ISM - Structure of Milky Way - Stellar population and galactic structure - Cosmology - Brief description of Galaxy morphology and evolution - Active Galaxies - Clusters of Galaxies.

03. Electrodynamics and Radiative Processes I

Review of Maxwell’s equations, and M.Sc. level electrodynamics - Motion of charged particle in E, B fields - Electromagnetic waves - Polarization and geometrical optics - Radiation of electromagnetic waves - Scattering of radiation (Thomson and Compton) - Bremsstrahlung and synchrotron radiation.

04. Quantum and Statistical Mechanics I (Quantum Mechanics)

[The Course will emphasize the functionality of QM rather than its mathematical or conceptual structure].

Overview of M.Sc. level quantum mechanics - Solution of Schrödinger equation in 1 d and potential motion - Quasi classical case, WKB - Hydrogen atom and the structure of periodic table - Perturbation theory - Fine structure and hyperfine structure (21 cm) - Quantum theory of radiation - Energy levels of atoms, and molecules and selection rules.

05. Methods of Mathematical Physics II (General Relativity)

Physical basis for GR - Tensor analysis - Geodesics, connection and curvature - Einstein equations - Schwarzschild metric (orbits and classical tests of GR) - Black holes - Gravitational waves - FRW spacetime.

06. Introduction to Astronomy and Astrophysics II (Stellar Physics)

Observational data on stars (types of stars, spectral classification, regions of HR diagram) - Basics of nuclear energy generation - Sources of opacity - Steady state stellar models (homologous models and multi-layered configurations) - Stellar evolution (simple analytical estimates and summary of numerical results) - Supernova and SNR - End stages of stellar evolution (white dwarfs, neutron stars and black holes) - Pulsars - Evolution of binary star systems - Star formation (including brown dwarfs) - Star cluster.

07. Electrodynamics and Radiative Processes II (Astrophysical Processes : Fluid dynamics, Radiative processes and Plasmas)

Basics of fluid dynamics - Hydrostatic equilibrium, with applications to self gravitating bodies - Instabilities - Accretion and winds - Shocks - Turbulence - Basics of plasma physics - MHD - Dynamos - Radiative processes in astrophysical systems: Bremsstrahlung, synchrotron radiation, Compton and inverse Compton processes - Macroscopic description of radiation field - Moments of radiative transfer equations and simple approximate solutions - Ionisation and recombination processes.

08. Quantum and Statistical Mechanics II (Statistical Mechanics)

Overview of M.Sc. level statistical physics - Basics of statistical mechanics and thermodynamics - Boltzmann, Bose, Fermi distributions - Applications to classical gases, electron degeneracy in white dwarfs - Photons Bose condensation and superfluidity - Ionisation and pair creation equilibria - Phase transitions - Elementary introduction to stochastic processes.

09. Astronomical Techniques I (Incoherent Detection)

Time and coordinate measurements - Atmospheric effects (absorption, seeing,) - Basics of telescopes - Noise and statistics - Photon detectors - Basics of photometry - Spectroscopy and polarimetry.

10. Galaxies : Structure, Dynamics and Evolution

Galaxies as self gravitating objects, virial equilibrium - Estimates of collision times - Collisionless Boltzmann equation and some steady state solutions - Globular clusters - stability - Spiral structure, bars and disc dynamics - Ellipticals - Galaxy morphology - Chemical evolution - Galaxy formation and evolution.

11. Extragalactic Astronomy I (Cosmology)

Friedmann models (geometrical and physical aspects) - Thermal history of the universe from $T = 1 \text{ GeV}$ to $T = 900 \text{ K}$ - Linear growth of perturbations - Anisotropies in CMBR and comparison with observations - Nonlinear evolution of perturbations (Zeldovich approximation, spherical top hat, basic idea of simulation results) - Segregation of baryons and dark matter- Very early universe and inflation - Clusters and superclusters - Overall structure of IGM-Gunn-Peterson effect - Quasar absorption systems - High redshift galaxies.

12. Astronomical Techniques II (Coherent Detection)

Partial coherence - Aperture synthesis and image reconstruction High angular resolution techniques and astrometry - Databases in astronomy.

13. Interstellar Medium

Extinction and reddening of star light, dust - 21 cm, galaxy rotation curves, HI distribution - Ionised gas, pulsar DM - HII regions - Cooling and heating - Shocks - Supernovae remnants - Phases of the ISM - Magnetic field and Faraday rotation - Cosmic rays - Molecular clouds and star formation.

14. Extragalactic Astronomy II (Radio Galaxies and Quasars)

Phenomenology of AGNs (Seyferts, Quasars, Radio Galaxies, LINERS, BL Lacs) with a survey of continuum, emission and absorption features of spectra - Black hole and accretion disc models for AGNs - Emission line regions (BLR, NLR) - Physics of jets and hot spots.

Appendix 3: Norms for NCRA staff members doing a Ph.D.

The norms for NCRA staff members who would like to register for a Ph.D. under TIFR Deemed University are as follows:

1. The research ability of the candidate will be tested in an interview by an NCRA faculty committee before he/she begins graduate school studies. This interview could cover the technical skills of the candidate, his/her understanding of projects that have been done in the past as well as the area proposed for doctoral research, and his/her understanding of basic physics. The committee for this purpose will be constituted by the NCRA Dean.
2. The academic requirements for obtaining the Ph.D. degree should be the same as for Regular Ph.D. students in NCRA. Specifically, the staff member should complete all the required graduate school courses and research projects. The points worth noting are (i) the staff members will be allowed two attempts at clearing each Graduate School course and (ii) staff members will have the same CPI requirements for courses and projects as those for Regular students of the NCRA Graduate School. The CPI for the staff members will be computed at the end of every 18 credits, which roughly corresponds to the number of credits per semester of the Graduate School. The detailed norms are outlined in Sections 3, 4 and 5 of this document.
3. However, bearing in mind the fact that the staff members will have parallel observatory duties, they would be allowed to complete the graduate school requirements in 5 years (as opposed to 2 years for Regular Ph.D. students).
4. Also, staff members will be allowed a maximum of 6 months in which to complete each “3 month” research project.
5. It is possible that the staff members may not be able to attend classroom lectures for some or most of the graduate school courses, due to observatory duties at GMRT. Hence the staff member be allowed to take the required courses as reading courses, if deemed necessary by the review committee. The review committee should decide which courses should be taken as reading and classroom courses. For reading courses, all courses should not be taken under the guidance of a single faculty member; preferably, not more than 2-3 courses should be taken under a single faculty member. The performance in the reading courses should be evaluated as per the standard graduate school norms, i.e. a combination of assignments, tests, seminars, and discussions, as deemed appropriate by the advisor. The member can also try to attend the lecture courses via video link.
6. A review committee should be set up for the Ph.D. candidate, similar to the Ph.D. Advisory Committees of NCRA Ph.D. students. This committee should consist of the guide, a member of the AAC, and the candidate’s reporting officer. In case the reporting officer is also the guide, the NCRA Dean should nominate an NCRA faculty member to be on the review committee.
7. There will be a review of the candidate’s performance every year, similar to the reviews of other NCRA Ph.D. students.