Optimizing telescope design for X-ray astronomy missions

Highlights
- Devising novel, robust, and efficient algorithms for structural optimization
- Developing high-performance computing software for aerospace simulations
- Optimizing the design of support structures of optical components employed in X-ray astronomy missions

Overview
Optimization plays a key role in industry: manufactured products are constantly optimized to improve performance and reliability. This research project focuses on a fascinating class of optimization problems known as structural optimization.

Structural optimization aims at improving the geometric design of product components. This is challenging for two reasons. First, the geometry of a design can be modified in infinitely many ways, and it is difficult to anticipate which geometric modifications are beneficial. Second, new designs must be tested in laboratories to verify their performance, which requires re-fabrication. This results in a difficult, expensive, and time-consuming iterative process.

This project aims at accelerating the structural optimization of X-ray telescope components. The University of Leicester has a strong expertise in X-ray astronomy and collaborates closely with the European Space Agency (ESA). For example, the University of Leicester has developed sophisticated glass optics for the ESA mission BepiColombo, which was launched in October 2018. These glass optics focus X-rays on the telescope’s detector, and are mounted on a support structure that must be precisely calibrated to the correct position, while being both lightweight and sufficiently robust to tolerate mechanical stresses due to vibrations during the telescope launch. This was a challenging task that has been overcome with intense efforts.

Support structures of this kind are ubiquitous in X-ray telescopes, but their optimal design depends on the telescope specifics. To accelerate the design process, we will model these 3D-structures using 2D-surfaces, also called thin-shell models, by exploiting the fact that their thickness is very small compared to their volume. Using advanced mathematics, we will use this dimension reduction to achieve faster numerical simulations. Theoretical efforts will be complemented with the development of a high-performance computing software. This software will be used to optimize the design of optics support structures of the X-ray telescopes developed at the University of Leicester.
Methodology

The first step of the project will be devoted to the formulation and analysis of thin-shell optimization algorithms. The student will develop a rigorous understanding of the mathematical models involved by learning and applying tools from functional analysis and calculus of variations.

The second step will focus on the discretization of these optimization algorithms. The student will employ results from finite element theory to preserve important geometric aspects of the original problem. To maximise research visibility, the student will develop an open-source library based on the open-source finite element software Firedrake.

The final step will be devoted to illustrating the advantages of the new thin-shell optimization algorithm. In this final phase, the student will collaborate closely with researchers from Space Park Leicester (METEOR project) and optimize optic support structures of X-ray telescopes developed at the University of Leicester.

Further Reading

- Munghan and J.F. Abel, *Fifty years of progress for shell and spatial structures*, International Association for Shell and Spatial Structures, Madrid, 2011.
- [https://www.firedrakeproject.org/](https://www.firedrakeproject.org/)

Funding

This research project is fully funded.

Home/EU Applicants

This project is eligible for a fully funded EPSRC studentship which includes:

- A full UK/EU fee waiver for 3.5 years
- An annual tax free stipend of £15,285 (2020/21)
- Research Training Support Grant (RTSG)

If you have any queries about the studentship packages please email **csepgr@le.ac.uk**
Application Instructions

The online application and supporting documents are due by **Thursday 27th February 2020**.

Applicants are advised to apply well in advance of the deadline, so that we can let you know if anything is missing from your application.

**Required Materials**

1. Online application form
2. Two academic references
3. Transcripts
4. Degree certificate/s (if awarded)
5. Curriculum Vitae
6. EPSRC Studentship Form
7. English language qualification (*If English is not your first language*)

All applications must be submitted online, along with the supporting documents as per the instructions on the website.

Please ensure that all email addresses, for yourself and your referees, are correct on the application form.

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<tr>
<th>Online application form</th>
<th>Deadline : 27th February 2020</th>
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<td><strong>Please refer to the application advice and link to the Apply Button on the <a href="https://www.epsrc.ac.uk/">EPSRC Studentships webpage</a>.</strong></td>
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<td><strong>Research Proposal/Proposal Statement</strong></td>
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<td>Please list the supervisor, code and title of the project you are applying to. You will also be required to upload the <a href="https://www.epsrc.ac.uk/">EPSRC Studentship form</a>. When prompted for the Personal Statement upload.</td>
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<td><strong>If you are applying for more than one project, please email your additional EPSRC Studentship form to <a href="mailto:Csepgr@leicester.ac.uk">Csepgr@leicester.ac.uk</a></strong></td>
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**Application Timeline**

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<th>Date</th>
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<tr>
<td>27th February 2020</td>
<td>Deadline for online application and supporting documents</td>
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<tr>
<td>13th March 2020</td>
<td>Interview invitations to be sent out</td>
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<td>25th – 27th March 2020</td>
<td>Interview days</td>
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<td>31st March 2020</td>
<td>Informal offers to be made</td>
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<td>15th April 2020</td>
<td>Deadline for acceptance of informal offers</td>
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**Application Tips and Advice/Application Status**

**Applying Early**

Although the deadline is 27th February, we advise you to apply early so we can advise you of any delay with your application such as missing documents etc.
Online Application Advice

- Check all the email addresses you have entered are correct before submitting.
- Check you have uploaded the CSE Studentship Form in place of your personal statement.

Once You Apply

Once you have submitted your online application form, and uploaded your supporting documents, a copy will be sent to the school for review.