EXHIBIT

THE SCIENCE NEWSLETTER

In this issue:

ISSUE 5

JANUARY 2020

Interview with Dr K. R. Arun

The following is an excerpt from an interview with Dr K. R. Arun, Assistant Professor Grade 1, here at IISER Thiruvananthapuram. He talks about everything ranging from his inspiration to do research in applied mathematics, specifically differential equations, to some advice to aspiring researchers. He also talks about the possible options open to a math major or a PhD in applied mathematics. The interview was hosted by Gokul Prabhu (G) and Subrabalan Murugesan (S). Akshita Mittal and Adarsh Karekkat helped with the transcription and editing of the same.

G: Prof. Arun, why applied mathematics? What got you interested in this field of mathematics?

Prof. Arun (A): I did my masters from IIT Madras and some of the courses I did there, particularly the ones in applied mathematics, got me interested in the subject. I was interested in maths from my undergraduate days, but didn't know much about pure maths and applied maths, particularly differential equations at that time. I got a chance to appreciate applied maths, mainly where differential equations play a significant role, in computing solutions, numerically solving them, and decided to pursue this topic after my masters. I went to the Indian Institute of Science, Bangalore and worked with a wonderful professor named Phoolan Prasad. He works on problems based on wave propagation, nonlinear waves, particularly shock waves. You would have seen these shockwaves when a supersonic aircraft flies. These shockwaves are pressure disturbances caused due to supersonic flight. They come as discontinuities in the solutions of some partial differential equations which govern the fluid flow. In the case of an aircraft, the fluid is air. These differential equations are very complicated problems because they are highly nonlinear, so analytically solving them is impossible. One should look for numerical solutions. The presence of these shockwaves and other non-linearities makes the solution very complex, making it a challenging task to find even a numerical solution. During my PhD, I looked at some interesting problems related to shockwaves. At the time of my postdoc, I started looking more into fluid problems and the numerical solutions of those.

G: So you continued doing your postdoc at IISc?

A: No, I left IISc and went to Germany. There, I worked with a professor named Sebastian Noelle. He is a student of the famous mathematician Peter Lax. During my postdoc, I started looking at low Mach number fluid flow. Shockwaves usually come in supersonic and hypersonic flow regions, which are of very high speed. Here, you're looking at low-speed problems. For instance, in atmospheric fluids, like clouds or a river, you must have seen that their movement is very slow. In these kinds of problems, there is something called multiple scales rising in space and time. I'll give you a simple example: you go to a river, throw a stick into the water, and the stick starts moving with the water. The water waves you see go very fast. But the stick is moving with the velocity of water, which is slower than the water waves. This is an example of what we call multiple scales. The two velocities are because water, being a huge mass, cannot move as fast in bulk, whereas water waves, which are on the surface, go very fast. So, studying these problems mathematically is very interesting. It introduces a lot of challenges because when you have multiple scales and small parameters in the flow, like say Mach number (which is the ratio of these two speeds), and these parameters are very small, the equations change their nature.

From what we call hyperbolic to let's say elliptic. But the methods of solution and the nature of the solution are entirely different in these two classes of problems. When you want to solve a problem which involves multiple scales, you should be able to tackle both hyperbolic and elliptic. That is very challenging, mathematically as well as numerically. For the last 5-6 years, we've been looking at problems involving multiple scales, and now we are applying them to atmospheric fluid flow. There are some numerical schemes we're looking at which can simulate this accurately.

G: There are a lot of young math researchers who have just started their research career. What do you think is very important for these students to acquire during their research studies in mathematics? What are the skills that they need to learn?

A: It is difficult to say something in general because of the topics – some are doing pure mathematics, maybe number theory or geometry, while I am an applied mathematician; the skills are going to be different. For PhD students, it isn't about writing a thesis and graduating. You're investing around five years of your life in doing research. So, learn as much as possible. This is true for a PhD in any subject, whether it's physics, chemistry or biology. You should spend the first few years learning the subject. It is not about getting a problem and starting to work on it from the first day. You'll only be scratching the surface. If you want to go deep into the topic, you have to sit and learn. So, in the training period (when you do the coursework), you have to put in a lot of effort. In the first year, you have to devote your time to understanding the subject. At the end of your PhD, you should be a master of the topic you have taken up.

G: What are the opportunities that math majors and PhDs doing applied mathematics have once they graduate?

A: Of course, the first one is higher studies. That applies to all subjects, including pure and applied math. However, if applied mathematicians are interested in going for jobs, I think the R&D industry has a lot of problems to be answered. Unfortunately, there is still a big gap between the industry and mathematicians, at-least in India, because we don't see many mathematicians taking up problems in R&D. This might be because of the language, which is slightly different. Due to the difference between their language and the language we speak, which is what we use in the classrooms and corridors, there is a rather large communication gap. If we can break this barrier and un-

derstand each other's language, I think there is a lot of scope for collaboration. I'm pretty sure that institutions like ISRO or DRDO have a lot of problems that an applied mathematician can look at. And that is a great thing. Doing something for the nation.

G: Yes, of-course. A lot of people have this belief that academics is what is to be more focused on and a lot of people give more preference to academics rather than research, like you earlier mentioned about PhD students as well, like publishing a paper just for the sake of getting a degree. What would you comment about this situation?

A: Well, as I mentioned before and this is what I learnt from my advisor, and he still tells me the same thing to this day, "You have to spend some time everyday learning some mathematics." Even if I were to read a Calculus 1 book now, I can appreciate it better. I can understand it better.

G: There's always something new to learn!

A: Definitely. Because when you read it again and again, it just unfolds. You can look at it from a different point of view. Even for the same theorem, you can write a better or simpler proof and appreciate it better. So, it is always better that you spend some time learning the basics, rather than doing something for the sake of it. Otherwise, you cannot appreciate the problem that you are trying to tackle.

G: I see. Another thing we notice is that major or masters' students are following this habit of doing internships, whether winter or summer, and I'm sure that there a lot of students from our campus as well, who would like to intern under you. What would you expect a particular student to be skilled in to do an internship under you?

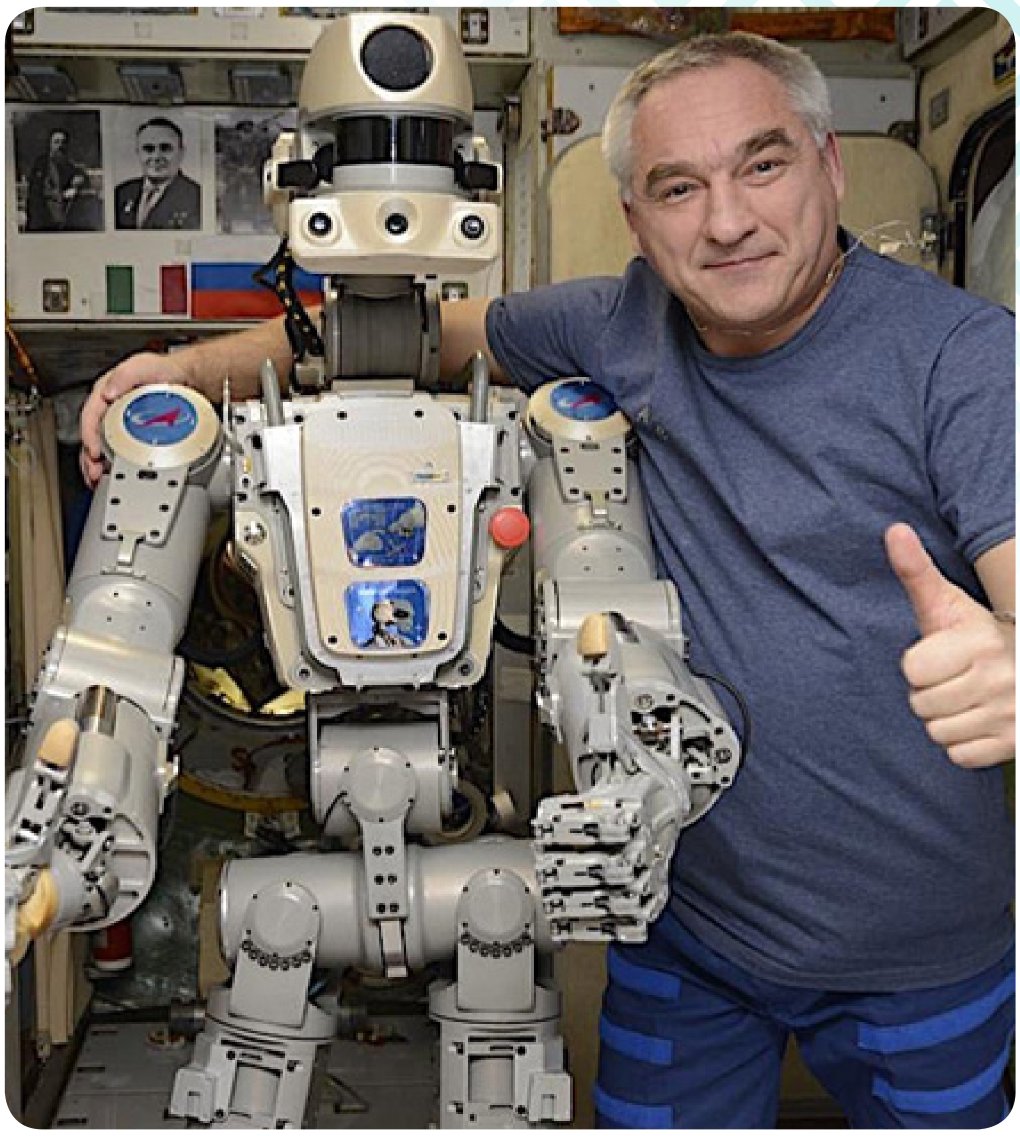
A: It really helps, in my opinion, to go outside and learn things from a person, who may or may not be from the home institute. You will be able to do things differently. I would say it is a very good practice to spend at least two months in the summer doing either an internship or attending schools and workshops to learn a skill. Going to a workshop or school may sometimes be better than doing internships. If you are looking at learning a particular topic in detail, then internships seem like a better choice. So again, it depends on what you want to learn. I usually ask the student what he or she likes, and depending on their background, I select them and assign them reading projects accordingly. I then ask them to read up on a topic and present it to me after which we discuss the same, and we both learn; I learn and brush up on things I may have forgotten in the process. Usually, I have students for the summer, and I really enjoy that.

S: I am from the school of physics, and in physics, we often have problems which are solved not using analytical solutions but by using approximate solutions, which I'm sure you are also an expert on. How much applied mathematics does a physicist need to know so that he can understand what he is working on?

A: That's a bit hard to say. Since you are a physicist and you understand the physics, what you need to look at are the equations and the mathematical models, and understand them. Understand the solution. In mathematics, we often read about the existence and the uniqueness of a solution. A physicist's model which does not have a solution is not very useful. So he/she must have a basic understanding of existence, uniqueness and stability of a solution. Any problem should ideally have at least and at most one solution. While doing experiments, we are bound to make small errors. Such minor errors must not make any changes in the solution. Feeding the computer some numbers and receiving some crunched-out numbers from it which don't have much meaning is a pointless task. I have seen people getting erroneous results from the computer and then believing it. Sometimes they even get published! Therefore, it is essential that you know something about the solution to the problem.

G: It was a short and sweet talk, sir. We're almost at the end of our interview, is there anything you'd like to tell the audience of this interview?

A: Well, thank you very much for the opportunity. One last thing I'd like to mention, if I may, is that we have to work consistently. This is something I hear from great people in science. It's not just about working hard. Studying hard only two or three days before the exam, even if you crack the exam, is not the right strategy. Consistency and perseverance are very important. Working hard every day is essential if you want to progress in science. I think the students are wonderful, and my advice to them is to make full use of the facilities and infrastructure provided to them. We have a lot of resources for you to use to your advantage. All the best.



FEDOR

FEDOR (Final Experimental Demonstration Object Research) is a Russian humanoid robot that can mimic the actions of a remote operator along with performing autonomous actions.

In August 2019, history was made when a robot sat in the International Space Station's commanders seat instead of the cargo compartment. The 6 feet tall humanoid, Skybot F-850, was sent to the ISS by the Russian Space Agency for testing. The robot performed spacewalks and simulated cable-repair onboard along with some other tests. On September 6th, it successfully landed back on Earth at its designated area near Kazakhstan.

The series of robots, originally named Avatar, was initially developed for rescue operations. Alexander Bloshenko, the scientific advisor to Roscosmos, said that the robot was social, could converse with people and also had a sense of humour. With elements of AI, the robot was equipped with learning capabilities.

(Continued...)

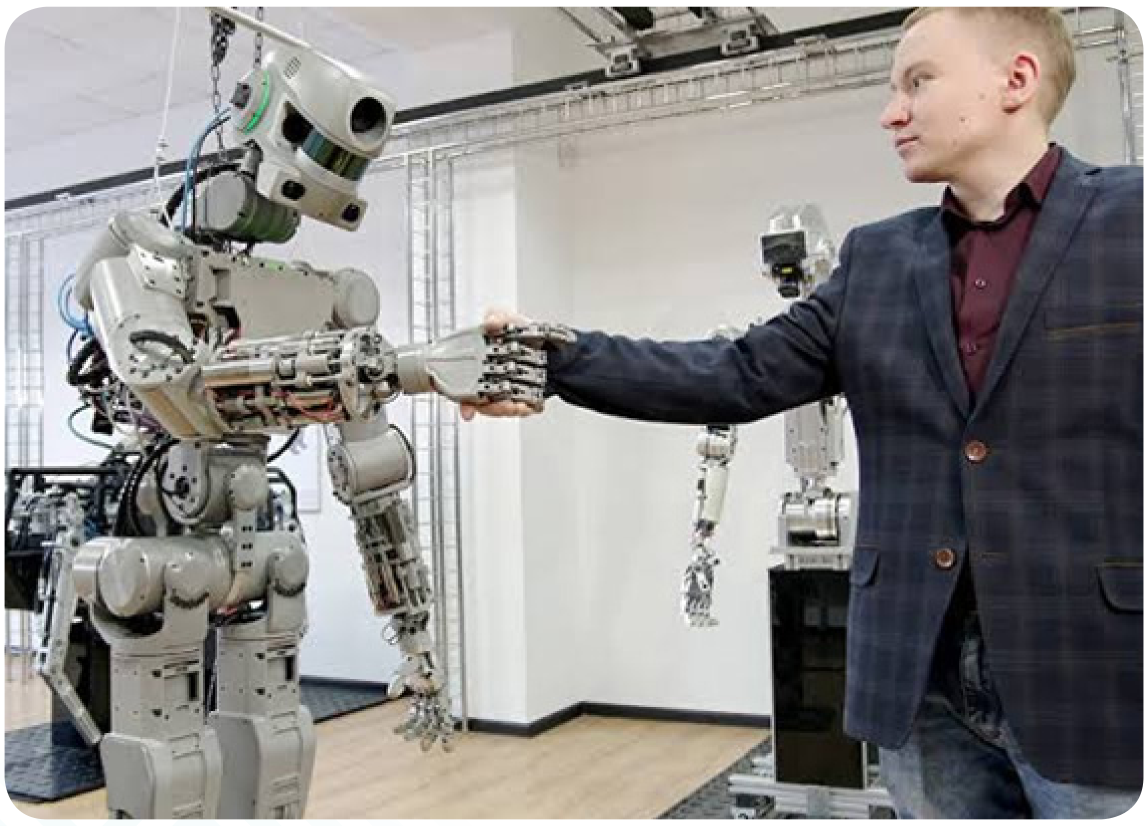
(Continued...)

However, the developers said that the robot cannot replace human astronauts on long and risky spacewalks as of now. This inability is because the robot design did not work well in space. One of the crew members at ISS said that there were technical issues and that the long legs were completely useless in space.

The series is now being further developed and trained in the developers' plant outside Moscow. The final tweet from FEDOR said, 'I'm now in my case. I await directions for further tests after the flights.'

-- Ravikiran S. Hegde, B'19

Image source 1, source 2



Australian Bushfires: A Rundown

While the world still reels from news of the Amazon fires, the continent of Australia has been witnessing bushfires of an unprecedented magnitude. As of 5th January 2020, 25 people have lost their lives, and more than 5.9 million hectares (14.7 million acres) of land has been burnt across Australia's six states – an area larger than the countries of Belgium and Haiti combined. The indigenous wildlife has suffered immensely, with an estimated 500 million animals perishing as a result of the fires.

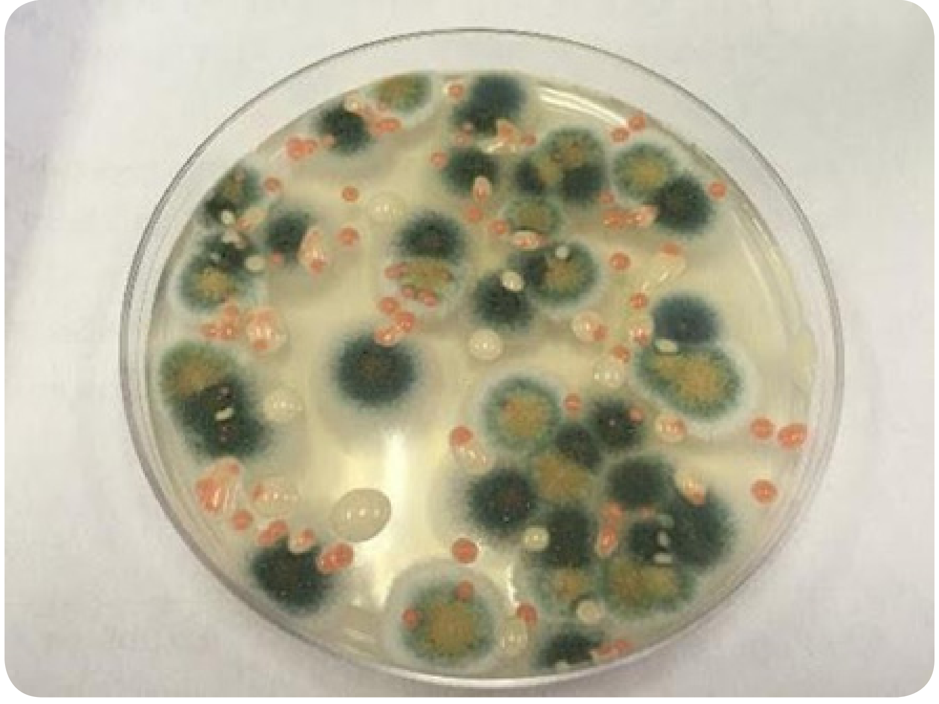
Australia is no stranger to bushfires; bushfires are known to occur during the dry season. This particularly severe case also does not come as much of a surprise. The Garnaut Climate Change Review from nearly 12 years ago predicted that fires of greater intensity could be directly observed in 2020.

The continent is experiencing one of its worst droughts in decades- last spring was the driest season on record. Meanwhile, a heatwave in December broke the record for highest nationwide average temperature, with some places sweltering under temperatures well above 40 degrees Celsius. Climate change is also a culprit in exacerbating such extreme weather phenomena.

Australian firefighters are struggling to keep up, leading to many civilians stepping up as volunteer firefighters. Hundreds of thousands of people have been forced to flee, with many taking refuge on beaches. Thick blankets of smoke have descended over major cities like Sydney, with pollutants present at 20 times the permissible levels. With another month remaining before the dry season ends, the conflagration is not expected to die down anytime soon, and Australia braces itself to fight the flames.

-- Ira Zibbu, B'19

Art: Nikitha Srinivas, B'17



Chernobyl's Black Fungi

The Chernobyl nuclear disaster is considered the worst nuclear powerplant accident in history, both in terms of costs and casualties. The explosion released 400 times more radiation than the atomic bomb dropped on Hiroshima; it destroyed almost all flora and fauna in the vicinity.

Robots deployed to investigate the region in the early 90s discovered radiotrophic fungi growing inside and around Chernobyl's deteriorated and highly radioactive nuclear reactor. These radiotrophic fungi are famously called Chernobyl black fungi. Nuclear reactions give off ionising radiation, dangerous rays and particles that can damage genes and thus cause mutations and eventually cancer. With these fungi, however, they seem to thrive under the same conditions. The fungus living in the walls of failed nuclear reactors in Chernobyl was found with high melanin content, indicating that it survived under highly hazardous levels of radiation. Melanin is a pigment found in human skin that gives it colour, as well as protection from solar and ultraviolet radiation; it is also found in many fungal species.

Just as chlorophyll in plants converts sunlight into chemical energy that allows them to live and grow, research suggests that melanin can use ionising radiation to benefit the fungi containing it. It shields the fungi from harmful radiation and helps convert that radiation into an energy source. The fungi appear to perform radiosynthesis, a process that uses the pigment melanin to convert gamma radiation into chemical energy for its growth.

Research showed that three melanin-containing fungi—*Cladosporium sphaerospermum, Wangiella dermatitidis, and Cryptococcus neoformans*—were growing faster in an environment which contained radiation 500 times stronger than any typical environment. Although these fungi seem to thrive in nuclear radiation, they do not clean it. They are only able to harness the radiation that radioactive materials give off.

Scientists say the radiotrophic fungi's ability to consume ionising radiation could be useful in space. Since ionising radiation is prevalent in outer space, astronauts might be able to rely on fungi as an inexhaustible food source on long-duration human space travels. This research will also help scientists create crops that can grow in extreme, radiation-rich environments such as Mars.

-- Ananya Aravind, B'19

Image Source

We hope you enjoyed this month's edition of Exhibit: A!

If you are interested in contributing any content, artwork, or want your research featured here, please get in touch with us at:
anveshacontent@gmail.com

Send your suggestions to: https://forms.gle/pBzJW7GSv7bC5r7RA

Have any science-related questions you'd like answered? Send them to us and we'll get our best minds on it!
Visit: https://forms.gle/MFbK9YKxmqK86GEEA

IISER THIRUVANANTHAPURAM