HOUSE OF COMMONS

Science, Innovation and Technology Committee

Oral evidence: UK Astronomy, HC 329

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Watch the meeting

Members present: Greg Clark (Chair); Dawn Butler; Chris Clarkson; Tracey Crouch; Dr James Davies; Katherine Fletcher; Stephen Metcalfe; Carol Monaghan; Graham Stringer.

Questions 1 - 71

Witnesses

I: The Lord Rees of Ludlow OM, Astronomer Royal and Professor of Cosmology and Astrophysics, University of Cambridge; Professor Catherine Heymans, Astronomer Royal for Scotland and Professor for Observational Cosmology, University of Edinburgh.

II: Professor Steve Eales, Head of Astronomy Group and Co-Director, Cardiff Hub for Astrophysics Research and Technology, Cardiff University; Professor Mike Edmunds, President, Royal Astronomical Society.

III: Professor Anna Scaife, Professor of Radio Astronomy and Head of Jodrell Bank Centre for Astrophysics Interferometry Centre of Excellence, University of Manchester; Professor Martin Barstow, Professor of Astrophysics and Space Science and Director of Strategic Partnerships Space Park Leicester, University of Leicester.

Written evidence from witnesses:

- Professor Catherine Heymans

Examination of witnesses

Witnesses: The Lord Rees of Ludlow OM and Professor Catherine Heymans.

Chair: The Committee is in session and today we begin the oral evidence in an important new inquiry into UK astronomy. We are privileged to begin our hearings with a very distinguished and expert panel of witnesses, starting with Professor Lord Rees of Ludlow. Professor Lord Rees has been the Astronomer Royal since 1995. He is a former president of the Royal Society and former master of Trinity College Cambridge. Among many illustrious awards, at the end of last year he was awarded the Royal Society's Copley Medal, "for being arguably the most distinguished theoretical astrophysicist of his generation", as it said in the citation. I was privileged to be part of that ceremony. Welcome, Lord Rees.

Joining us virtually is Professor Catherine Heymans, who has been the Astronomer Royal for Scotland since May 2021. She is professor of astrophysics at the University of Edinburgh and director of the German Centre for Cosmological Lensing at Ruhr University in Germany. Among many awards, she received the Max Planck-Humboldt research award and the Royal Astronomical Society's George Darwin lecture award, on "Observing the dark side of our universe".

Thank you very much indeed. What a terrific privilege to have both the Astronomer Royal and the Astronomer Royal for Scotland opening our inquiry. I will hand over to my colleague Tracey Crouch for the first question.

Q1 **Tracey Crouch:** Good morning. My constituents are always keen to tell me whether they think I am spending my time in this place wisely. Therefore, I start by asking: why does astronomy matter? Lord Rees, I will start with you.

Lord Rees of Ludlow: I would answer that in a number of ways, depending on whether I am thinking of the public or science. It is the most universal environmental science. Throughout history, everyone has looked up at the same night sky, wondered about it and wanted to understand it. Also, everyone who has understood evolution and Darwin would like to go back further and ask, "Why is the Earth there at all? How does it fit into the rest of the universe?" These are the questions that astronomy is trying to ask. It asks them by using high technology. It has been at the frontiers of technology through the centuries. Clocks have always been the highest tech of their generation, in a sense, and telescopes were the first instruments to require professionals to handle them. It is an ancient science. Its role is partly exploratory, but it is also part of fundamental science. School pupils will know that we are trying to get a unified picture of the laws of nature.

The laws of nature are the laws that govern the micro-world, and gravity governs the large-scale universe. They are in separate compartments now; there is no unification. The only way we learn about gravity is by

looking at places where it is very strong—stars and galaxies—and discovering black holes. Even in the case of gravity, it is technologically important. Satnav would not work properly if you did not put in the corrections from Einstein's theory. So there is already a link of that kind. There are also huge links in instrumentation—that used for astronomy and that used for other areas of science, including medicine.

You will probably hear more from later witnesses about the educational role of astronomy. It attracts young people. Very young kids think of space and dinosaurs as the two most fascinating things, and we want to build on that and not let it evaporate as they get older. In universities, astronomy is a very attractive aspect of physics-based courses. It is an important part of that, and it is growing.

Finally, we realise that astronomy is naturally very international. It ought to be, as it is looking at a universal part of nature. It involves observing from all over the world, and it involves international consortia. Those most important to us in the UK are the European Southern Observatory, which is building the world's biggest telescope, and the European Space Agency. Despite Brexit, we remain a member of them both. The European Space Agency has a low profile compared with NASA, but if you look at the science bit, they are pretty comparable. The European Space Agency's leading projects have been fully a match for NASA's scientific projects. NASA is much bigger because it has a human space flight programme, etc. That is an introduction; I will stop there.

Chair: A very comprehensive one; thank you very much.

Q2 **Tracey Crouch:** Professor Heymans, following on from Lord Rees's answer about why astronomy matters, what specific benefits does astronomy give to UK society and what tangible impact does it have on people's everyday lives? We heard about satnav, but what else? If you were talking to the ordinary person in the street, why would you say looking up at the stars matters to them?

Professor Heymans: The Government's goal is for the UK to become a science superpower, and astronomy is the route to doing that. One of the big problems in the UK is a deep-rooted cultural misconception that science is boring and maybe too difficult. Unfortunately, if you are a girl, some people will think it is not for you. Yet people with those beliefs will also tell you that they saw a gorgeous full moon the other night and that they have seen shooting stars. They often wonder whether there is life elsewhere in the universe. Astronomy is genuinely loved in the UK. If there is a story about astronomy discoveries, it goes far and wide in the media.

As Lord Rees said, astronomy covers all the sciences. We have astrochemistry, astrobiology, astrophysics and astroinformatics. Astronomy is a genuine gateway into science. If you want to counteract the cultural belief we have, which affects teenagers' choices at school when they are trying to decide what to do at advanced level, astronomy

is the best way. I have been to thousands of primary schools and have yet to meet a child who does not love space. Astronomy is our gateway into science. If you want a science superpower status, you have to focus on the generation that is coming up, and astronomy is a really good way of doing that.

You asked about the technological implications. By definition, astronomy is very blue-sky research. We look up at the skies and do not really know what we are going to discover, but so many things come out of that. Lots of people get into the science and technology, and the instrumentation, because of the astronomy, and lots of things follow on from that. It is a great investment and a great hook, because everyone loves looking up at the sky, and that connects people to science.

Tracey Crouch: Thank you very much.

Q3 **Chair:** Thank you, Tracey. Lord Rees, we have talked about astronomy generally, but what about the UK in astronomy? What are our particular strengths in this field—apart from your good self?

Lord Rees of Ludlow: The various bibliometric types of evidence that the Royal Astronomical Society has gathered show that we are in the top two or three in the world in most respects, and we have a leading role in many of the consortia. In fact, half the papers from the European Southern Observatory projects have a British author. We are very active in a lot of consortia—the bilateral as well as the big international ones. We are high up on the list of prizes and recognitions, etc.

I would like to expand on what Catherine said about the subject matter expanding hugely. We have had space astronomy for the last 40 or 50 years. We have the ability to detect gravitational waves by the most amazing technology, detecting something with the thickness of a hair at the distance of Alpha Centauri—one part in 10^{21}. That is the extent to which we are leading the technology. Now we have discovered that the galaxy is far more interesting because there are planets around most stars. Just as the everyday planets go round the sun, there are probably 1 billion planets rather like the young Earth in our galaxy. Do any of them have life on them? We do not know, but that is now a serious question to ask. One can get the light from one of these tiny planets around a distant star and learn enough to know whether it has vegetation on it, and that sort of thing, within the next decade. This makes it a very interdisciplinary subject, impinging on science.

Another thing that I am sure the Committee is concerned about is the fraction of top talents training in scientific areas. It is certainly true that the number of people training in physics has gone up now that more than 40 universities have astronomy as part of their physics courses. As Catherine said, it attracts the public. There is a large number of amateur groups around the country. My final comment on that front—going back to the first question—is that the public are ambivalent about some sciences that seem threatening as well as fascinating, such as nuclear or

genetics, whereas evolutionary biology and astronomy have an unambiguously positive image. The public are interested in Darwinism and, in the same way, they are interested in where the planets came from and why they are there.

Q4 **Chair:** That is very interesting. Are you content that we are exploiting the UK's strengths to the maximum extent we can?

Lord Rees of Ludlow: In the last decade we have suffered the same funding constraints—cuts in real terms from research councils, etc.—as all the rest of science. I am sure you have heard from other scientific areas about the problems. We are suffering from the fact that the real-term value of the grants we get from the STFC and so on has gone down. Also, as astronomy is a far more international science than any other, we are suffering more from problems with visas and immigration with respect to foreign talent. We are much more international than most. Most of our papers involve international authors; those from my department certainly do.

Chair: We will come to some more detailed questions on that, starting with Dawn Butler, and then Graham Stringer.

Q5 **Dawn Butler:** Thank you both for your fascinating evidence today. Lord Ludlow, we are always saying that the UK is a science superpower and that we are ahead of the game or leading the pack. I am not quite sure if that is true, but I wonder how we are using our position in the UK internationally to maximise international collaborations.

Lord Rees of Ludlow: I wish the phrase "science superpower" had never been introduced. We should be heading towards it, but whether we are at the moment is a more general political issue.

Catherine can probably speak more about what we are doing with the resources we have, but on the educational front, a lot is being done to attempt to stimulate interest, which makes the public more aware. It is not just a few specialists who care about this. In terms of international involvement, we are especially strong in this country. The fraction of people from overseas who are graduate students, especially postdocs in our institutions, is especially high in astronomy, because they work jointly on big international projects.

Q6 **Dawn Butler:** Thank you. Professor Heymans, you said that we are becoming a science superpower in the UK. Do you agree that we can do more internationally?

Professor Heymans: We can always do more. We have a great history of astronomy in the UK. Lord Rees quoted you the numbers from ESO. Even though we pay only 17% of the subscription to use this amazing suite of telescopes at the European Southern Observatory, we gain 30% of the time because it is allocated based on excellence, and British astronomers are excellent at what they do. But we cannot be passive about this. As Lord Rees said, we have had decades of flat cash funding.

If we look at advances in China and India, where they are going with their astronomy programmes is genuinely exciting. In a decade or so, are we still going to be the science leaders if we are not investing in this area?

We are very lucky in the UK. We are often the first people that international collaborations come to, because we have such a strong record in all areas of astronomy. That is quite unique to the UK. No matter what astronomy topic you are interested in, you will find an international world expert at one or more of our UK universities. We have a breadth of knowledge, with which we have managed to surf the last funding drought. Perhaps that is too strong a word, but it has been hard.

We really benefited from Horizon 2020 when we were part of it, so I am pleased that we are back in it. In the universe sciences, the UK got 25% of the ERC grants when we were a member. These are examples of how well respected we are when we are assessed on our excellence. We can build on that because astronomy is a route into science, but we cannot expect to surf on that experience. We need to continue to invest and fund this area, which is growing rapidly internationally.

Q7 **Dawn Butler:** Does that mean that we are behind China and the US?

Professor Heymans: Not right now, but if you look at what they are investing in, you will see, for example, that India had their fantastic lunar landing recently, and they have a rover going around, which is brilliant. They are doing really exciting research, and there are UK astronomers collaborating with these countries, so it is win-win as long as we can continue to have these bilateral agreements.

The UK Space Agency now has a programme where we can do bilateral agreements with space agencies other than the European Space Agency. That is good but, again, the funding levels are challenging. The central theme of the written evidence is that we have the expertise and we can do so much, but we are being limited. It is really important that the Astronomy Advisory Panel road map stated that "funding for human capacity is now the main limiting factor for our national science capability in astronomy". I could not agree more. I am pleased that the STFC now has an increase in its exploitation grants—it has built in an increase of £2 million per year for the next few years—but we can do so much more with more funding.

Q8 **Chair:** We will now go into some questions, from Graham, on that funding, particularly the research councils. I was struck by what you both said about funding being constrained, and flat cash. For this Parliament, science funding is doubling, and I think it has been flat real in the previous Parliament. In your view, Professor Heymans, is it a problem for astronomy within the envelope of science funding?

Professor Heymans: Funding within the STFC is split into different areas; it quite rightly firewalls the international projects from UK

projects. We have our subscription to ESO, which is absolutely essential, and funding of the Square Kilometre Array, the big radio telescope that will be absolutely amazing when it comes online. Then we have the exploitation grants, and investment in other infrastructure facilities. The problem is that that exploitation grant, which funds all our ability to take advantage of these facilities, has had flat cash, yet our astronomy community has grown by about 20% in the last 10 or 20 years.

Chair: I see. Let me turn to Graham to follow up with some specific questions on that.

Q9 **Graham Stringer:** To follow up on what Greg just said, Lord Rees, you said that astronomy had problems similar to those of other parts of science, but my recollection is that when the PPARC was abolished just over 10 years ago, the STFC did not transfer as much funding to astronomy as it had been receiving under the previous funding council's regimes.

Lord Rees of Ludlow: That may well be true, but it is important to reiterate what Catherine said about the allocations to the international collaborations. Even if they go up, it does not help us unless we have a corresponding increase in the grants to support people to work on those projects.

Q10 **Graham Stringer:** That may be true, but what I am trying to get at is whether, over the period since the STFC was established, astronomy has, almost by accident, fallen behind other sciences in funding. Have the Government tried to justify that, or is it just a casualty of an un-thought-through funding decision?

Lord Rees of Ludlow: I do not have the details. Obviously, the emphasis has been on biomedical sciences, but I think there is an acceptance that space is something that we in the UK should expand. It is a mixed point. To most of us, the establishment of UKRI has been a negative, in that it has increased bureaucracy, etc. and decisions on priorities are less well addressed now than they were in the previous system.

Q11 **Graham Stringer:** That is really interesting. Does astronomy suffer from having the UK Space Agency as a funding body as well as the STFC? Are there complications around that issue?

Lord Rees of Ludlow: There are some. Of course, Brexit did not affect CERN or the European Southern Observatory, because there were separate protocols. In the case of ESA, it was slightly more complicated because it has the mandatory science programme, which was okay, whereas with the extra programmes like Copernicus, which is more Earth-oriented, and Galileo, what has happened subsequently is that we have, essentially, got back into Copernicus but not Galileo. Those complications are downsides of Brexit.

Q12 **Graham Stringer:** Galileo is an EU project.

Lord Rees of Ludlow: Yes.

Q13 **Graham Stringer:** The European Space Agency is not an EU body, is it?

Lord Rees of Ludlow: No, it is not.

Q14 **Graham Stringer:** I am slightly confused by the answer because they are different beasts.

Lord Rees of Ludlow: ESA and ESO are both international conventions separate from the EU but, in the case of the European Southern Observatory, it is clearly all science, whereas ESA has the mandatory science programme to which all nations contribute by a standard formula, but it also has other programmes, like the Ariane rocket that was mainly supported by the French, and Galileo, which we wanted to be in but are no longer.

Q15 **Graham Stringer:** Via Google, I have tried and failed to trace what has happened to the Royal Observatory at Greenwich. Has that been a casualty of the changed funding? What has happened to it?

Lord Rees of Ludlow: I need to go into slightly more ancient history, there. The history, as you probably know, is that it moved from Greenwich in the 1960s to Herstmonceux, because Greenwich is not a good place to do observing. Then it became far more sensible to invest in overseas telescopes in Australia, the Canary Islands and Hawaii. The Greenwich Observatory is now part of the National Maritime Museum.

Graham Stringer: That is all it is, now.

Lord Rees of Ludlow: For the last 30-plus years it has been just a museum. Incidentally, that is why the title of Astronomer Royal, which used to be a real job, running the observatory, is now just an honorary title—because there is no actual scientific research being done at Greenwich.

Q16 **Graham Stringer:** I have one final question, on a different strand, for both of you. You both gave very good reasons to Tracey why astronomy is an important, exciting and stimulating subject, but science is international, isn't it? How do we justify funding in this country when, as far as I know, astronomers in the United States and throughout Europe share their findings? Why is it important to do the research and get the product of that research here, as opposed to sharing other people's research?

Professor Heymans: That is an interesting question; there are different ways to answer it. Let's say we want to answer the big science question of whether there is life elsewhere in the universe. NASA is currently thinking about a next-generation telescope called the habitable worlds observatory. It is going to be an absolutely fantastic beast out in space, looking for signs of life on other planets. A huge amount of technology investment will go into that project, if it happens—this is 20 years in the

future. We want to be part of that. I do not think we want to wait and see whether other countries discover it.

These are the steps that are taken to answer the big science questions. We want to be part of the science that answers the really fundamental questions that capture everyone's imagination, such as, "Where did we come from?" Thinking also about the economic advantages, and the money and investment that goes into industry, lots of written evidence was submitted by Airbus and Clyde Space in Scotland, for example. These technology centres work with the academics to answer the big science questions. It is the big questions that push us, the technology and the advances. In the UK we need to be part of that; we do not want to just wait to see what other people find.

Graham Stringer: Thank you. Lord Rees.

Lord Rees of Ludlow: I am rather shocked that you would even contemplate the idea that we should drop out.

Graham Stringer: We try to ask the difficult questions.

Lord Rees of Ludlow: "If we don't get smarter, we will get poorer," is the right slogan. We have no natural resources, but we have intellectual resources, and in all the sciences and arts we ought surely to be punching above our weight if we can.

Chair: Thank you for that slogan: "If we don't get smarter, we will get poorer." Carol Monaghan is next.

Q17 **Carol Monaghan:** Thank you very much. It is really great to hear from both of you this morning. I want to talk about overseas talent, Lord Rees, which you have mentioned already. In various inquiries we have heard about the level of visa fees for overseas researchers and people working in the technology sector. Skilled worker visas are among the most expensive in Europe. Spousal visas recently increased by over £10,000 and ultimately, I think, they will increase to £38,700. How does that sit with attracting the best talent from across Europe and the world?

Lord Rees of Ludlow: It does not, of course. It is a real own goal. This is true across the whole of science and technology. It is probably more true in a subject like ours, simply because we are more international; we are in international partnerships for everything we do. But this is an own goal for British high tech in general, making it harder and less welcoming for foreign talent to come here.

Q18 **Carol Monaghan:** Professor Heymans, where does that sit us, in the next 10 years? We have just heard that we are world-leading. How is that going to impact our position?

Professor Heymans: I am really proud that here at the University of Edinburgh we now have a policy of paying all the visa fees and NHS surcharges for our international members of staff. I think we are quite unusual in that, but I hope to see universities rolling it out, because the

charges are prohibitive for early-career researchers. Often, our home-grown talent wants to go and explore the world, and that is great for us, because they come back as faculty with all that international knowledge. We often recruit from abroad. If we want to recruit the best, the charges are prohibitive for the salaries that they earn. I am proud that we do that at the University of Edinburgh. I would like to see grant agencies allowing us to use grant funding to pay these fees and charges—to make it possible. We navigate the landscape that we are given, to make science possible.

Q19 **Carol Monaghan:** It seems a bit counterintuitive that we are getting grants from the UK Government to carry out research and then paying that money back to the UK Government in order to get the best researchers.

Professor Heymans: I agree.

Q20 **Carol Monaghan:** I was not aware of that at the University of Edinburgh; it is really helpful for the Committee to hear it. I know that some technology companies are able to pay the visa fees, too, taking that as part of their cost of recruitment. That is fair enough, but what about the spousal visa? If you have an early-career researcher, are they likely to be earning £29,000 to bring a spouse over?

Professor Heymans: If it is £29,000, yes. When it was the £38,000 that was initially planned—

Q21 **Carol Monaghan:** I believe that that is the ultimate aim, but it has been paused for a moment. Maybe the Chair can—

Professor Heymans: There was an immediate concern within our community about the £38,000, because postdocs do not earn that much. A postdoc is a postdoctoral researcher, so it is after their PhD. Yes, they do earn more than £29,000.

Q22 **Carol Monaghan:** It would be problematic at the higher figure.

Professor Heymans: Yes. I do not know whether we will have time to talk about equality and diversity—

Q23 **Carol Monaghan:** I was just about to go on to it. My colleague Chris Clarkson is going to cover some of this, but I want to ask a little about it.

My next question is about promoting astronomy and how you use your role to do that. You have mentioned equality and diversity. This week I read an article in *Times Higher Education* that talked about female students in STEM. I know that astronomy is better placed, in terms of the number of female students, but the article said that female science undergraduates are twice as likely to experience sexism as their peers on non-science courses. Many reported being patronised and belittled and that behaviour going unchallenged by staff. Is that something that you recognise, as a woman working in this environment?

Professor Heymans: Yes. Unfortunately, it is something that I recognise. As I said at the start, it goes back to a deep-rooted cultural conception of what science is and the way in which it is portrayed in the media and in films. It is all part of our culture. We are working hard to try to change that.

I am the first female Astronomer Royal for Scotland in the 200 years that this role has existed. Change is happening. It is something that we are aware of. I am sure that you will discuss this later with the Royal Astronomical Society, which is taking statistics to look at bullying and harassment in our field. The problem exists. It is not a problem that is localised only in astronomy; it is a science-wide problem. There are various ways in which we can try to mitigate it. The most important thing is that we are talking about it, so I am really glad that you have brought it up.

Q24 **Carol Monaghan:** Can I push you on the other bit of the question: how do you promote astronomy? In particular, how are you promoting it to young girls?

Professor Heymans: The crunch point is in the teenage years, when they make the decision about whether or not they are going to carry on with science. That is a real crunch point, in the early teens. In primary schools, you do not see any difference between girls and boys. They all want to go into space; they can all tell you about the planets. There is no difference. Something happens early on in high school, where they make that decision.

How do you change that? I have been working with groups who would not normally engage with science. The people who most influence teenagers are their parents. If they are struggling with maths, girls, in particular, will go to their parents and say, "Oh, I'm finding this really difficult." Their mum will say, "Don't worry, I couldn't do it either. Don't worry about it. It doesn't matter." It does matter. Every subject is difficult and challenging, and science is so exciting.

My effort at the moment is to engage with people who do not normally engage with science. That is why astronomy is so powerful—everyone loves the night sky. We have a huge grassroots community of enthusiastic astronomers across the whole of the UK. They are traditionally known as amateur astronomers, but I hate that term. These people know more about back-garden astronomy than I do, as the Astronomer Royal for Scotland. We need to harness that community interest, so that these people go into schools, show kids things through the telescope and show people that science is for everyone.

We have to change these cultural conceptions. It is changing. When I was at university, I did not have a single female lecturer. It was not that long ago that I was there, and now 30% of lecturing staff in astronomy are female. We are getting there, but it is slow progress.

Chair: The final question to this panel is from Chris Clarkson.

Q25 **Chris Clarkson:** To be honest, you have answered quite a bit of what I wanted to ask, Professor Heymans. I wanted to drill down on how inclusive and diverse the astronomy community is—in particular, how it is engaging with those groups who do not necessarily think of themselves as likely candidates for a STEM career. You have touched on the experience of women in STEM, but could you think about some of those other groups as well: people from disadvantaged communities, minority ethnic communities and the LGBT+ community? Have you found that any specific initiatives have been better at engaging those people? Are you seeing a change in the make-up of the people coming to study astronomy?

Professor Heymans: There are two things that I would like to highlight briefly; I know that we are short of time. At the moment, the STFC has something called the Wonder Initiative, which focuses engagement on communities that are underrepresented in astronomy. Part of its theme when it is allocating funding is to ensure that it is focused on all these communities.

I particularly want to highlight a group called Science Ceilidh, which is currently embedding early-career researchers within youth groups. It is a really fun project. The idea is that you get these young scientists in the community groups, and they ask questions like, "Are aliens out there?" They are genuinely interested. As Lord Rees said, we have the technology to answer those questions in the future—to really search for life elsewhere. Connecting these communities with academics is happening.

The problem is funding. Yet again, we go back to funding. The funding for this area is often the first thing to go. There is a written submission by the Euclid Consortium, which is a fantastic space mission that will explore the dark universe. When its budget cuts first came, it was the outreach programme that went. It was required to deliver the science goals, so when it had to cut funding, it was the outreach programme that went. We now have this fantastic UK project, where we have a huge investment, but we do not have a serious outreach campaign for it. Science not spoken about is science not done—that is a quote from Anne Glover, our chief scientific adviser. We have to invest in these outreach programmes, because that is our best way of improving diversity in science, which is absolutely necessary.

Chris Clarkson: Thank you very much, Professor. That is an excellent quote; I will be stealing it and passing it off as my own. Lord Rees, would you like to add anything to that?

Lord Rees of Ludlow: I agree with what Catherine said. I would like to use this opportunity to say that one of the reasons we want to have a broader post-16 curriculum for everyone is the reason she alluded to: to stop women being discouraged. At the moment we have a system whereby if you are turned off science for any reason at the age of 16 and

drop it, that forecloses going to a strong university course at 18 to do science, so we need to have a broader curriculum at 16 to 18.

Carol Monaghan: As we have in Scotland.

Lord Rees of Ludlow: In my view, we also need to have more mature-level and part-time access to universities, because so often people drop out of doing anything in the STEM area at 16. That constrains their lifetime opportunities.

Chair: I thank both Astronomers Royal for a terrific opening to our inquiry—an overture in the best sense, which anticipated themes but was a masterpiece of evidence in itself. Thank you very much.

Examination of witnesses

Witnesses: Professor Steve Eales and Professor Mike Edmunds.

Q26 **Chair:** I invite our next panel of witnesses to join us here at the table. They will give evidence in person.

I am very pleased to welcome Professor Steve Eales, head of the astronomy group and co-director of the Cardiff Hub for Astrophysics Research and Technology at the University of Cardiff. His research looks into the origin and evolution of galaxies, using telescopes all around the world and in space. Professor Eales was awarded the Herschel Medal by the Royal Astronomical Society for outstanding contributions to observational astrophysics.

Joining him at the table is Professor Mike Edmunds, who has been the president of the Royal Astronomical Society since May 2022 and is emeritus professor of astrophysics, also at the University of Cardiff. Among other things, he is chair of the astronomical heritage committee of the Royal Astronomical Society. Intriguingly, he also stars in a one-man play about Sir Isaac Newton, entitled "Sir Isaac Remembers…", so he is a man of many parts.

Thank you very much for joining us this morning. I will start with a question to Professor Edmunds. I ask you to consider the point about the UK's standing. How do we compare with other countries in terms of our astronomical assets, research base and research outputs? Professor Lord Rees talked a bit about citations. Perhaps you might expand when it comes to the assets, in particular.

Professor Edmunds: Historically, the UK has done extremely well in astronomical research, and that continues. Lord Rees mentioned citations, which are always a difficult beast to handle. You have to do it with a degree of care. If you look at citations of astronomical papers around the world, the UK comes in either the top three or two in astronomy and space physics, the other places being the United States—obviously, a much larger economy—and Germany, which also does quite well.

I was googling away, as we always do. If you ask, "What are the top 15 universities for doing astronomical research in the world?", three are in the UK. Those are records of achievement from scientific peers. Obviously, a lot of stuff is anecdotal, but, as has been said, we do very well in research collaborations—projects such as the SKA, ESO and so on. It is true that people like to collaborate with the UK, because they find it good value and good at running things.

It is difficult in scientific terms to talk about return on investment. You can talk about investment return on investment and what comes back in cash, in development funds and so on. However, in terms of sheer academic achievement—to put it in that way—or knowledge base, the UK does very well at returning in astronomy.

Chair: Very good. Let us go into a bit more detail, especially on international programmes. Dr James Davies is going to ask some questions on that.

Q27 **Dr Davies:** Is this country effectively exploiting opportunities to lead international astronomic programmes? The question is to either or both of you.

Professor Eales: We are not exploiting them as well as we could. We are doing quite well. The recent invention of this bilateral thing for the UK Space Agency has been very good, because for the first time we can have deals with other countries that do not go through ESA. That has been very good, but it is a fairly small-scale thing and there is a lot more that we could do.

There is another thing that worries me a bit. Everyone has been saying how good the UK is in astronomy. That is right. Historically, in terms of quantity of research, we were probably No. 2; in quality, we were probably No. 1. In quantity, the US always won, but in quality, we probably did better. However, a lot of other countries are coming up and are now quite competitive with us. France and Germany put a lot of money into astronomy. Professor Heymans mentioned India and China.

It is not a bad thing that there is a larger pool of competition, but we are probably falling behind a bit, not in terms of the money that we put into assets—there have been big UK investments in things like the Square Kilometre Array, the LSST and Euclid—but in terms of the money going into the people. That is the problem, and has been for quite a while. We cannot always exploit these. When we are trying to compete with the French and Germans, we have one hand behind our backs because we do not have enough people—postdocs and students—to work on the actual data.

Professor Edmunds: Can I add a little on that? A lot of projects find that you can put a lot of money into well-spent capital, but the problem is that the project may be 10 years long, and our grant funding typically works on a three-year period, not a 10-year period. To have stability of

funding that allows you to go right through that project and exploit it, those two timescales are not well matched. We would welcome some scheme that gave not necessarily more money—though yes please, if you can, obviously—but more stability. Often it is the stability of funding that causes the problem, not the funding itself.

Q28 **Dr Davies:** Two clear points have been raised there. Can we quantify the level of investment in people that we are looking for?

Professor Eales: More, basically. I do not know how much. You could compare the UK with France or Germany; I am not sure about the actual difference, but clearly we invest much less.

It is also interesting to note the way in which research funding is done in the UK. It is very much a case of some person with a faculty position, like me, applying for grants and then funding the younger person on a three-year timescale. It is highly competitive. It is quite flexible, so in a way that system is quite good for taking advantage of new opportunities, but there are major disadvantages. You do not get the long-term funding, because there is only a three-year postdoc for people. You do not put sustained amounts of money into certain research areas.

The other thing is the postdocs themselves, who do not have an opportunity to have their own money. In the old days—back in PPARC's day—we had postdoctoral research fellowships, so someone could come out of a PhD, have a bright idea and get their own fellowship. Now they have to rely on some older person having a grant and employing them on that person's idea, rather than their own idea. I think that the structure of research funding is not all that it might be.

Q29 **Dr Davies:** I move on to a different topic: dark skies. I have some awareness of this locally. I know that the Clwydian range has been applying to the International Dark-Sky Association to achieve recognition. There is an all-party group on dark skies here as well. Professor Edmunds, how much of a problem is light and satellite pollution for UK astronomers? How can this best be addressed?

Professor Edmunds: It is becoming a worldwide problem. There are two aspects to it. One—which is certainly a local problem, to put it that way—is whether you can see the sky when you walk out of your house. Can you see the Milky Way, or have we become a race that no longer lives half of our life seeing the universe around us, and all that that implies for our philosophy and our interest in the skies? That is one problem, and you can do something about it. The Commission for Dark Skies is trying to make sure that we at least have reserves where you can go and see that.

However, a major problem for professional astronomy is going to be the satellite constellations. We have made and are now making representations to international bodies that we have to be careful to preserve the opportunity to do research in the skies. If you have

something like 10,000 satellites all running in a constellation together, with shiny outsides, you see them in your telescope when they go past and they can cause major problems in interpretation. Even worse is if you have that number of telescopes with communications equipment that is not working absolutely perfectly but is leaking into side frequencies. That is the end of your radio astronomy.

It is not an insoluble problem, but the problem is that the commercial interest behind those satellite constellations and so on is extremely high. There is a lot of money going on that. It is very important that we get international regulation. We are not saying, "Don't do any of it," just that a lot of it can be mitigated if you make sure that satellites are not reflective, you have very strict things about your electronic equipment and you have a way of turning it off if it does not work. There are things that can be done, but there has to be good will in that, and it has to be international. In terms of the long-term future of astronomy, it is extremely important.

Q30 **Dr Davies:** Are the UK Government or other bodies in the UK currently sufficiently engaged in making those representations internationally?

Professor Edmunds: I was hoping that you could tell us that. Obviously, the Space Agency, too, is very involved in talking about this, but we welcome and will continue to push for good interaction.

Chair: We will find out in the course of our inquiry whether the Government and the institutions are doing enough. Let me turn to Carol Monaghan.

Q31 **Carol Monaghan:** I have to say that dark skies are only part of it. When you live in the west of Scotland, there are other weather issues that sometimes prevent you from seeing it. I do not know how many times the aurora has been active, but nothing has been available in Scotland.

Professor Eales, you have expressed concerns about the lack of UK launch capability and what that means for the sector. I have two questions. First, can you expand a bit on that and how we get a thriving astronomy sector with limited launch capability? Secondly, we have just seen Shetland get a licence for vertical launch. We have had a launch in Cornwall, albeit one that was not as successful as we might have wished. Is that helping? Do we need to see more of this?

Professor Eales: Personally, I love space, so I like seeing rockets go up and stuff. From a professional astronomy point of view, it is not the launch capability that is so important but the thing in the budget for making satellites and space things. You can always pay people to launch your satellites. There are so many private providers of launch vehicles nowadays. The issue is not so much the launch but having our own properly funded space science programme. That will be the interesting thing. Of course, that has huge numbers of commercial spin-offs.

Q32 **Carol Monaghan:** We took quite a lot of evidence on this when we

looked at launch sites across the UK. Do you think that when launches start happening there will be a proper programme behind that? I can see that having something like that could be the catalyst for a lot of other activities in the field.

Professor Eales: I hope so. One of the really cool things nowadays is that people can build CubeSats, which are very small satellites. In the old days, it used to be that NASA would launch rockets; that was all, and it cost a huge amount of money. Now it is proliferating. I hope that things like the Cornwall and Shetland launch facilities will lead to more sciency things, rather than just commercial things. It would be great to see science satellites going up as well.

Q33 **Carol Monaghan:** You talked about a programme or getting some structures in place. Who would develop all that?

Professor Eales: You would hope that it would be the UK Space Agency, in collaboration with commercial companies and universities.

Q34 **Carol Monaghan:** Does education have a part to play in that as well?

Professor Eales: Education has a huge part to play. As people have said, astronomy and space are two of the greatest stimulants to encourage someone to go into science and engineering. For my part, I was eight years old when Apollo 8 went around the moon and showed the pictures of the Earth rising over the moon. That is why I am an astronomer—I got excited by the space programme. The space programme has a huge educational role.

Carol Monaghan: Thank you. You mentioned CubeSats, so I will get in a wee plug: Glasgow makes more CubeSats than anywhere else in Europe.

Professor Eales: Well done.

Carol Monaghan: Thank you for mentioning them.

Q35 **Chris Clarkson:** I would like to turn now to funding. I suspect that I already know the answer to the first part of this question: do you think that the sector is adequately resourced financially? Secondly, do you think that certain projects sometimes fall between two stools, with the STSC on one side and the Space Agency on the other? Would having a single pot of funding make it easier to monetise some of these projects? I will start with Professor Edmunds.

Professor Edmunds: No, we would like more money—that is the obvious answer to the first question—for everybody; we are not pleading a special case here. We know that it has been financially difficult over the past 10 years, but that has taken its toll. We would like to see funding at least moderately increased, particularly in terms of flexibility and predictability that we could plan against.

On your second question about the two sides, yes, there is a problem, but I do not think it is a major one. There is some dual work involved, in

the sense that some projects have to apply to both agencies and it is double jeopardy, as it were. Some of it will be for the capital and some of it will be for the exploitation, and so on. That gets difficult, but I do not think that having a single pot will necessarily do it. What we need to do, perhaps, is to look again at the procedures—the way in which the applications are made and the way in which the STFC and the Space Agency talk to each other, so that it is not a pulling war, or something like that, but a joint endeavour.

Steve may disagree with me, but I do not think it is a major problem. It is a problem that can be fixed, but I do not think that having a single pot would necessarily be the answer. Negotiation and setting up slightly better procedures would probably cure it, but that is a personal view.

Professor Eales: I will talk about the dual funding first. It is swings and roundabouts; there are arguments in both directions. There are problems of communication between the two at the moment. I am involved in the Euclid space observatory, which was funded by the UKSA, but to get people to work on it you need to go to the STFC. That means that you are competing with everyone else. It is frustrating when you have the spacecraft up there and you cannot get people to work on it. I am not making special pleading for space astronomers, because everyone is in the same situation, but we have a disadvantage when we are working with our French and German collaborators in the Euclid team, as they have more funding for actually using the observatory than we do. That is a major issue.

To go back to your first question, obviously everyone wants more funding, as Mike said. The funding on assets over the last 15 years has not been bad. We have had major investments by the UK in the Square Kilometre Array. Congratulations to the politicians who made that decision, which was a really good thing. We have had major investments in various space missions. The assets are fine, but the amount of money going to fund students and postdocs has not kept pace. As a consequence, it is very tough nowadays to get funding for postdocs. In the 1990s, I remember that it was very easy: you just put in a mediocre case and PPARC would give you a postdoc.

Professor Edmunds: Not true.

Professor Eales: No, but now it is really tough. You have to put in absolutely brilliant cases to get anything.

Q36 **Chris Clarkson:** To pull on that thread, when people come to apply, do you find that there are certain areas of astronomy that are less likely to attract funding or are less popular when it comes to receiving funding? Are there areas that get monetised more readily?

Professor Eales: There are always fashions in astronomy. People will say, "This area is really exciting," and then go into it. Those areas tend to attract a lot of grants. There are unfashionable areas that do not get so

much, but it is hard to know what to do about that because partly it is the community doing that, rather than Governments.

You can point to areas which have not got funding, which is a problem. An area where the UK was totally leading the world in the 1990s was astronomy in the submillimetre waveband. The UK built the world's first submillimetre telescope, the James Clerk Maxwell telescope, in the 1980s. We built the first submillimetre camera in the 1990s, with a team led from Edinburgh. In the 1990s, that was the most cited instrument after the Hubble space telescope. In 2010, the Herschel space observatory, another submillimetre observatory, went up. Because of the strong UK involvement, we led 40% of the key projects for that European survey. We were leading the world. However, because of the financial crisis, in 2015 the STFC signed over the James Clerk Maxwell telescope to the East Asian Observatory. Since that time, we have lost the lead in submillimetre astronomy. That is one area where financial constraints have created a problem.

Q37 **Chris Clarkson:** Is there anything you would like to add, Professor Edmunds?

Professor Edmunds: I do not immediately recognise particular areas where you say there is no funding, apart from Steve's example where perhaps things have moved on. It is very tight, and it is probably more by luck than judgment that we do not have areas that are completely starved.

Chair: During this inquiry we will need to get to grips with why astronomy is suffering these particular problems, because from 2015 to the present the public science budget has increased from £9 billion to £20 billion a year, but what we are hearing very clearly already is that that buoyancy is certainly not being felt in astronomy. We will drill down on this. I believe that Graham wants to pursue some funding questions on this.

Q38 **Graham Stringer:** Professor Eales, you say in your written information that the process for applying for funding is not transparent, and basically you think there is some prejudice in relation to which institutions get favoured in funding and which do not. Can you elaborate on that? Who is being favoured and who is not?

Professor Eales: Within STFC there is the astronomy grants panel. That panel looks at proposals by people like me for postdocs. That is an incredibly level playing field. It is an extremely well-run system and is much fairer and more transparent than, for example, the system in the European Research Council, so it is really good. The problem arises at the higher level where you are not getting individual postdocs but grants to do big infrastructure projects. It is not even the case that there is some skulduggery going on. A lot of the funding tends to go to a few universities.

Graham Stringer: You are talking about the golden triangle.

Professor Eales: Edinburgh and Durham actually do quite well also in astronomy, but essentially it is the golden triangle. It is not that there is anything bad going on, but to give an example that we came across recently, the Square Kilometre Array is an amazing capital investment by the UK. We are playing a major role in this global radio telescope and it will be brilliant, but there is funding necessary to do a lot of the data reduction. It is not exactly funding for research but funding for stuff that is connected to research. What happens is that people in the know—several universities—will put in a proposal to STFC to do this. It will then be peer-reviewed, but essentially there will be one proposal from this kind of cartel of universities and every other university is not even aware that there was an opportunity.

Personally, I would favour a system in which every time any public money is to be used there is an open call so that every part of the UK can be involved. Again, I emphasise that it is not anything bad. It is not that the golden triangle is doing bad things exactly; it is just that because of their connections they know how to work the system a bit better.

Graham Stringer: They come out on top.

Professor Eales: Yes.

Q39 **Graham Stringer:** To explore what you said in your previous answer to my question about it being easier to get money for postdocs when PPARC was there—I think that was what you said—

Professor Eales: Yes.

Q40 **Graham Stringer:** Is that just tightness of funding, or is it prejudice against astronomy? Historically, this Committee has had a couple of punch-ups with the STFC. It tried to abolish the British Antarctic Survey, and we had quite a big fight on its behalf. As I mentioned to Lord Rees, the funding for astronomy slipped, to put it politely, when the STFC was put up. Is the difficulty in getting funding for postdocs part of that process, or is it just tight money?

Professor Eales: Another issue, which, to be fair, I should mention, is that the number of people—the faculty—doing astronomy has increased by a huge amount since the 1990s. There is far more astronomy by faculty in the UK fighting for grants, so there is competition. It is harder because there is more. On your other question, I do not know the answer to that.

Q41 **Graham Stringer:** Do you have a suspicion?

Professor Eales: In the astronomy community we always have a suspicion that any Government do not value blue-skies research and they are putting all the money into stuff that is immediately commercial. It is a suspicion. That is all I can say.

Professor Edmunds: If I can add a supplementary comment, we do not expect most postdoc students to become astronomers. We have had an increase in astronomical starters, as Steve mentioned, as the subject has grown, and obviously you have to count that, but one of the real values of astronomy and astronomical research is the training and skills transfer that it gives. People coming out of an astronomy PhD are a very valuable product. If they have done, say, a couple of years postdoc as well in some particular thing—AI, large data these days, detectors or whatever it is—they are really valuable people. They go out into the community and the economic system of the country and they are very valuable. It is not that we necessarily want to train more astronomers; we want to provide these really good people who will be the movers and shakers in science and technology in the years to come.

Q42 **Tracey Crouch:** As a supplementary to that point, both of you alluded to the insecure status of many astronomical researchers and staff in UK universities. What practical steps do you think we could take to improve the job security of UK astronomers?

Professor Eales: One thing that would be great would be to bring back postdoctoral fellowships. A postdoc is usually someone paid out of a grant administered by some senior academic, but a postdoctoral fellowship is something you give to a student who is just starting. They come out of a PhD and have a good idea, and a postdoctoral fellowship allows them to do their own thing for a few years. Those are very effective because they allow people to develop all kinds of leadership skills and creativity. Often, those are the next generation of faculty. The fellowships give a little bit more security because it is under their own control. I suppose that longer-term postdocs would be better in terms of security than the three-year postdocs. Three-year postdocs are very difficult because, if you get one of those, you spend the first year learning what to do. You do a year of research and in the final year you are applying for jobs again. It is a really difficult system to be in.

Tracey Crouch: Professor Edmunds, do you have anything to add to that?

Professor Edmunds: It is about stability of funding. If you have a grant or stability of funding and you are able to employ it over a longer period of time, then it will be easier for planning careers.

Q43 **Tracey Crouch:** I want to ask a second question, but it is at the other end of the education spectrum. This was inspired by Professor Eales's earlier answer about being an eight-year-old boy seeing the moon landing. I have an eight-year-old boy and I am one of those mums who pays close attention to the curriculum that he is learning. What are your views on primary education science teaching? I am very conscious that they learn history in a very chronological order, whereas in science they tend to go from dinosaurs to something else and then back to dinosaurs. Maybe this is a question I should have asked Lord Rees, but is there great interest in how we teach very young children science?

Professor Eales: I do not know much about the primary curriculum; I know a little bit about the secondary curriculum. I think it is very important. When I give talks in primary schools the kids are incredibly excited. By teenage years they are harder to move, but primary school kids are great. Mike, do you have a view?

Professor Edmunds: My view is that the first important thing in any education system is enthusiasm. As you say, in primary schools there is a lot of enthusiasm. I do not care whether you jump around among the moon, dinosaurs, food safety or whatever it is as long as it is interesting, stimulating and the scientific method is creeping in in how you approach problems. I suspect that the greater problem is in secondary education in going further and keeping that enthusiasm without dumbing it down, making sure that that is across all social, ethnic and gender groups and nobody is excluded from that. To my mind, that is probably where the problem lies, and some curricular stuff could possibly address that.

As far as the universities are concerned, you would like your students to be enthusiastic about their subjects and to be prepared to learn and do the stuff, and to say, "Yes, it is difficult, but I want to do it because it's really interesting." That is fine. It is the enthusiasm you have to keep and not kill it.

Q44 **Tracey Crouch:** The RAS—I note on its website—produced some wonderful online learning during covid for home learning. That was particularly focused on primary children as well. I am a non-scientist on the Committee; I am the sporty one. In sport, we say that you create that habit early on and that is a habit you have for life. I assume there is a very similar attitude in science. If you start that interest early at primary school, that will hopefully be carried on throughout. I wondered particularly about the RAS interest in the development of the curriculum, which has obviously been done with online support, to get that kind of early enthusiasm, such as Professor Eales's reference to the moon landing.

Professor Eales: Early enthusiasm is important. I did a lot of interviews of scientists at one point and one of the questions I asked them was, "When did you first get interested in science?" I was surprised at the answers. First, it always occurred at about the same age. Between six and eight seemed to be the critical age. The other thing, a bit depressingly, is that it was never anything at school that triggered the interest. It was always parents, watching the moon landing, science fiction or something. I thought it was a bit of a shame. Schools developing or encouraging that kind of interest is very important, but how to do it is quite tricky sometimes.

Professor Edmunds: That is why our outreach programmes are important. Schools do what they can. I am sure improvements could be made, but that is why you have outreach because it reaches people in different ways, and that is very important.

Chair: Therefore, it is down to you as well as schools. It is interesting to know from an expert. Finally, on this panel, I turn to Dawn Butler.

Q45 **Dawn Butler:** Thank you both. I am going to talk about diversity and inclusion now in astronomy. I think 2024 will be a year when lots of people will be telling the truth about what they are experiencing in their workplace. What is important in that journey are allies. Professor Edmunds, your written evidence describes some shocking levels of bullying and harassment across the sector, especially among women, lesbian, gay, bisexual and non-binary astronomers. What do you think is the reason for that, and how can it be tackled?

Professor Edmunds: I wish I knew. It is not unique to astronomy at all.

Dawn Butler: No, it is not.

Professor Edmunds: As you know, bullying in the Houses of Parliament is not unknown. We did a survey. That survey and the recommendations on what we discovered within it will be fully published soon. You have read some of it already in our submission. We were surprised, but we have not really got comparable data on other sciences as to whether we are anomalous within the science. So our first attitude has been to find out what is going on, and, as you say, it does not look terribly good.

The question is then: what do you do about it? As a professional society, we have no real employment levers or whatever to pull and we cannot formally do much. It is really the employers who have the prime responsibility in sorting this out. That is not to say that we would not want to help people to do that. For us, it would be the universities or the research councils which are the employers involved.

What we can do, though, is monitor the situation and see how it changes. We can talk to everybody. One of the things people are beginning to do is talk about this now to find out what is really going on. How to tackle it is a very difficult thing. Do you do a full disciplinary tribunal in every case or whatever? No; you try to prevent it; you try to stop it happening before it gets to tribunals and help the victims of it to get over it and have a successful career.

We need to talk with the agencies and evolve with them and the universities ways of doing this. There will be quite a lot of negotiation and talking to try to understand the problem and how you tackle it. How you do that is not immediately obvious.

Q46 **Dawn Butler:** Is everybody on board, or are some people saying that is just woke nonsense, or that kind of attitude?

Professor Edmunds: I have noticed in the past a certain amount of, "Get over it; be more robust," or whatever, which obviously will not be very helpful. So, yes, there is some resistance, but it has to be talked through and people have to be made aware of it. I think that in a fair number of cases people are just not aware of what they are doing and

the effect it can have. That, surely, can be tackled. If they are people who are aware of what they are doing, a disciplinary process is needed. Evolving those systems that are fair and effective for everybody will take a little time, but at least it is being addressed now, which was not the case until very recently.

Q47 **Dawn Butler:** I think Professor Heymans, from whom we heard earlier, was going to inspire a whole load of women to get involved as well. Representation matters. Professor Eales, do you think there should be mandatory diversity and inclusion reporting for publicly funded programmes?

Professor Eales: Yes, because that increases transparency. That is an easy thing to do.

To go back to the other issues you raised, I can speak only for my own departments. In my own departments I can think of one person who might be anti-woke, but most people are on board with the fact that we need to increase diversity and tackle issues of harassment and bullying. Diversity has got better over the past 15 years, as Professor Heymans said, in terms of gender, but astronomy is still very much a middle-class profession and there is not much ethnic and socioeconomic diversity.

As Professor Heymans said, ideally you would send people into schools in areas that historically do not send a lot of people to university, and you try to give them role models and show them it is practical to do that. The problem is that although most astronomy departments and the STFC are generally very positive about outreach—we all love talking to people about astronomy—a very small amount of money goes into this kind of thing. To make a difference, you need programmes that put a lot of effort into doing this.

Dawn Butler: Thank you both for the work that you are doing in this area.

Chair: We thank both witnesses for their written evidence, followed up by answers to our oral questions today.

Examination of witnesses

Witnesses: Professor Anna Scaife and Professor Martin Barstow.

Q48 **Chair:** I invite the next and final panel of witnesses this morning to join us at the table. Professor Anna Scaife is professor of radio astronomy at the University of Manchester, head of the Jodrell Bank Centre for Astrophysics and co-director of policy at Manchester. Obviously, Jodrell Bank is one of our foremost and indeed most iconic institutions. We also have Professor Martin Barstow, who is professor of astrophysics and space science at the University of Leicester, and is director of strategic partnerships at Space Park Leicester. Thank you both very much for joining us today.

Perhaps I can start with a question to Professor Scaife. Tell us a bit about the contribution that Jodrell Bank makes to UK astronomy. In that context, perhaps you can tell us how it joins up with international partnerships around the world.

Professor Scaife: I think Jodrell Bank is seen as an iconic place in the UK for astronomy. That is not just because there is a giant telescope there, which I hope everyone on this Committee has seen, but it definitely helps. The historic nature of the observatory is extremely important. I do not know whether everyone is aware that Jodrell Bank is a UNESCO world heritage site for science. That is based not only on its history but the fact that it has been an active radio astronomy observatory since its inception, and continues to be a world-class radio astronomy observatory.

The telescopes on site are fully operational; they are cutting-edge instrumentation. The Lovell telescope is still the third largest fully steerable radio telescope in the world. The UK's national radio astronomy facility, e-MERLIN, is operated from Jodrell Bank. These days it also hosts the headquarters of the Square Kilometre Array Observatory, which is the world's first intergovernmental organisation for radio astronomy. So Jodrell Bank makes a huge range of contributions.

On the outreach side, the discovery centre at Jodrell Bank welcomes thousands of visitors every year, including many schoolchildren. It is also home to the Bluedot festival, which celebrates science as part of culture and is instrumental in reaching those harder-to-reach audiences for science. People who might not be interested in science come for the music and stay for the science, and everyone has a nice time.

Chair: Let us go into a bit more detail on these themes, starting with James Davies.

Q49 **Dr Davies:** We have heard about Jodrell Bank but, more generally, at what level are the UK astronomical telescopes and observatories in terms of development, and what barriers do they face?

Professor Barstow: I think we are in a very good position. We benefit hugely from our membership of the European Southern Observatory and access to major facilities, including the forthcoming extremely large telescope. That will be the largest telescope in the world, and probably will remain so for almost a decade once it comes on line in the next two to three years. Similarly, in the space area, our participation in ESA allows us as a relatively small country to play on a huge international field, and it very strongly enables the competitive position that we already have in astronomy. As for the missions that ESA provides, as a country we could not build them on our own. We have a shared approach to this. It includes things like the James Webb space telescope, which is clearly at the forefront of space-based astronomy at the moment, in which the UK had a leading role. So I think we are very well placed.

The difficult bit is to maintain that going forward. We do have leadership roles in a range of ESA missions and a range of instruments that go on these ground-based telescopes. There are some gaps. Steve Eales mentioned one around the submillimetre wavelength where we have lost a bit of ground. I think it is important for us to look across astronomy and make sure that we do not allow any holes to emerge in our capability, because when we are observing objects in space or from the ground, we need to look at all the kinds of wavelengths that might be available to us, so having that complementary coverage from those various facilities is critical.

Q50 **Dr Davies:** The international facilities are critical to UK astronomers. Before we move on, is there anything you need to say about facilities based within the UK itself?

Professor Barstow: Apart from radio, it is hard to do ground-based astronomy from the UK. The weather is not great, as I think has been alluded to. From a UK-only perspective, the UK Space Agency bilateral programme has been a very important new contribution to what we do, because it allows us to grow capability. If we want to be part of international consortia, we need to have something to bring to the table. Therefore, making sure we invest locally in new technologies so that we can say, "We can do this for you," is really important; it is making sure we get technology development right. The bilateral programme is also important for developing our industrial partnerships and helping our space industry to compete for large contracts within ESA, for example.

Q51 **Dr Davies:** As for the international dimension, you mentioned the extremely large telescope, or at least the wider scheme into which that falls. I have seen mirror segments being polished in St Asaph by Wrexham University in my constituency. That is a contribution towards it, which is great, but what is access to those international facilities for British astronomers like? I know that particular telescope is not yet up and running.

Professor Barstow: Do you mean for observers, as opposed to industry?

Dr Davies: Yes.

Professor Barstow: It is perfectly straightforward. These facilities are available to UK astronomers universally. We have a right to apply for time on them. How well we do depends on how well we write our applications. We do well because we have a vibrant community that has a lot of good ideas. To maintain our levels of access we need to support that community. We discussed in some of the earlier parts of this evidence session some of the issues around that, so I will not repeat that.

Chair: I turn to Katherine Fletcher, who has some questions on AI. I should have mentioned in introducing Professor Scaife that she holds a fellowship at the Alan Turing Institute for discovery in AI in data-intensive astrophysics, so the questions from Katherine will be relevant to

Professor Scaife.

Q52 **Katherine Fletcher:** Welcome down south, Professor Scaife. Fortunately, the universe is vast; it throws vast amounts of data at you as much as any human being can immediately access, and we have helpfully now started on the foothills of inventing this thing called AI, which is designed to deal with vast amounts of data. What are the potential applications of AI within UK astronomy?

Professor Scaife: They are huge. You say that the universe is throwing as much data as a person can handle. The universe is throwing more data than a person can handle. If you look at the facilities that we are building at the moment, for example the SKA telescope, we are talking of exabyte-scale volumes of data within the next few years. That kind of data is brilliant because it contains so much scientific information, but it is also a massive hurdle. Extracting that information is very difficult when you have that volume of data; so artificial intelligence is absolutely crucial, moving forward into this new era of astronomy, not only for extracting the information but doing so in a timely fashion, if you want to be able to get the science out of the facility within the scope of a career.

Q53 **Katherine Fletcher:** For instance, is it spotting a supernova?

Professor Scaife: It is everything. Spotting a supernova is a great example. It is trawling through time domain data to spot rare events, or different types of events like supernovae going off, and doing much more mundane things that have historically been done by eye, such as looking at all the galaxies in an astronomical observation and saying, "What kind of galaxy is this?" Historically, you could get an astronomer or grad student to look at the data, but these days there are so many galaxies coming out in the data that there just are not enough people, and it is not practical to employ enough people.

Q54 **Katherine Fletcher:** Is it counting numbers of planets, maybe assessing planetary light emissions—

Professor Scaife: And identifying which of those planets are interesting. It is exactly those kinds of things. How do we not miss them in the data? How do we find that needle in the haystack?

Katherine Fletcher: You have a galaxy and a universe of data coming at you.

Professor Scaife: Exactly.

Q55 **Katherine Fletcher:** How is your access? Recently, we have done an inquiry on AI; we are still conducting it. The protein scientists are excited and need the servers because they can work out perhaps how to solve diseases. Crop scientists are excited. There is a list. How is astronomy doing in getting access to those exabyte-scale systems?

Professor Scaife: It is a mixed bag. There has certainly been some very good progress recently. The new large-scale computing facilities going in

in Edinburgh and Bristol specifically for AI research will be absolutely instrumental in enabling this. There is a lot of capital investment in the computing but, in order to do the work, you need the people who are there to do the day-to-day operations and data handling. Ninety per cent of artificial intelligence is dealing with the data. The data is also the currency. If you do not have access to the data, it does not matter how good your algorithms are.

Q56 **Katherine Fletcher:** Are there any current data access barriers or do you perceive any to be coming? Fingers crossed, you are freeing up a bit of grad student time when the data is being processed through the box.

Professor Scaife: The grad student will be able to work on the processed data; they will look at the output. In terms of barriers, it is really about effective data curation. Access to astronomical data has generally been very good historically. Astronomy data is much more open than other types of scientific data, sometimes subject to a proprietary period. Having access to the data in principle is generally not a problem. It is the practicalities of it that is the limitation: being able to put the data somewhere you can use it, being able to move the data around, and having the data in a curated state.

Q57 **Katherine Fletcher:** Okay; so, it is the funding to unlock that which is a crucial part of the picture.

Professor Scaife: Exactly.

Q58 **Katherine Fletcher:** Is the reverse true? Is UK astronomy data teaching AI anything?

Professor Scaife: Certainly. This is again one of the benefits of having what you would probably refer to as somewhat more ethically agnostic data; there is no personal data coming down from the sky. You can develop algorithms much faster because you do not have to work around those kinds of security measures. Also, the volume of data we have is absolutely perfect for developing some of the more cutting-edge areas of AI such as the foundation models that are increasingly being used. You are probably more familiar with foundation models like the GPT models that underlie ChatGPT. Those kinds of models can underlie scientific research as well and other forms of analysis, but in order to build and train them you need to have large volumes of data. Astronomical data is one of the types of data you could use to build these foundation models—and we are, of course.

Q59 **Katherine Fletcher:** That is really interesting. You can, effectively, use the volume of information that you are getting to run these models hot and see if they break or make them work better.

Professor Scaife: From a scientific point of view, you want to examine the biases in the models and you want to be able to produce well-calibrated uncertainties from your models. You need to know how

confident the AI is in what it is telling you because it will give you an answer, but whether that answer is correct is the question.

Q60 **Katherine Fletcher:** I have a very short last question. Obviously, Jodrell Bank has been operating for such a lengthy period of time, both receiving signals from space and sending them out. How would you rate the likelihood of the aliens following that beam and landing back in Cheshire?

Professor Scaife: Let me see. If "The Hitchhiker's Guide" is to be believed—

Katherine Fletcher: Very good—42.

Professor Barstow: The Vogons could be out there already.

Katherine Fletcher: If aliens are listening, follow that beam. It will be very interesting. Thank you, Chair.

Q61 **Tracey Crouch:** I guess this sort of follows on, but not from that last question. Professor Barstow, how successful do you think the UK is in translating the astronomical research and technology into commercial products?

Professor Barstow: I think we are doing a much better job than we used to do. We have been working quite hard on this for 10 to 15 years, trying to change the way we do it and change the agenda, which goes back some time now. I like to think I have been at the forefront of some of that as a member of the STF Council in promoting the ideas. We cannot really choose research on the basis of whether it makes a commercial opportunity. We need to work in the interfaces between the research and the businesses that might wish to use it.

Research England funded something called the connecting capability fund for higher education institutions a few years ago, which was a really good start at doing that. It put a decent amount of money in, a few million pounds, into various institutions to help broker those relationships. That is the kind of thing we need to be doing more of.

Many academics are quite happy to work with industry, but they do not know how. They do not often know whether their ideas are relevant, so we need to develop that interface and create the opportunities and create the support, because, of course, we have to create space within a normal working day for people to do that. Universities are under a lot of pressure to deliver teaching and research, which is quite right. If you want us to do something else, we need to make space for people to do that, and that is where underpinning support is becoming particularly important.

If you look at the REF, there are many case studies referring to astronomy in the recent REF outcomes. We are doing some really remarkable things, but we can do better. We need to support the move in that direction.

Tracey Crouch: If we are to do better, that integrated partnership model—

Professor Barstow: It is about developing those integrated partnerships. The Space Agency is at the forefront of this through its investment in the development of clusters for space particularly, although that is not just astronomy, but astronomy is an important part of what we do in space. Many astronomers are engaged through the development of those regional clusters, and I lead one of those for the midlands. We are at an early stage there. We have been running for about a year. The prospects are really good as long as we keep the momentum going.

Q62 **Tracey Crouch:** In her evidence at the start of the session, Professor Heymans talked about other countries—other nations—that are catching up with us in terms of excellence around astronomy. I was struck by her comments on China. For the whole session, I have been wondering why it is interested in this. Why is it desperate to catch up with the rest of the world, as she used the phrase? Is this the potential area of why it is so keen?

Professor Barstow: I think it is one element of it. The track record of translating high-tech facilities or ideas from subjects like astronomy into industry is pretty well established through those case studies that I mentioned. Certainly, that is an element. People see particularly the space side of this, but it also extends to ground-based astronomy as being a very fruitful area for growing industry. The potential growth of space—I am sure you have done a recent examination of how space is going—is really large for the UK and for the world as a whole. This is a way we can get access to part of that growing market and the expanding cake. She is right: this is an element that they are all looking at. That is why we need to keep our eye on the ball. Things are moving very quickly. We cannot sit on our hands, otherwise we are going to get left behind.

Q63 **Carol Monaghan:** I will just ask a quick question. We heard earlier about some of the issues around diversity. We have heard that the number of women is increasing and that we are not getting the same number of people coming through from other groups such as ethnic minorities. Once we increase diversity and we get people in, how good are we at keeping them in the sector? Maybe Professor Scaife can start that one.

Professor Scaife: It is something that is very often overlooked. There is a move to push people into a sector, but then if you immediately lose them, you have done more damage than anything else. I would point out that at a professorial level in astronomy the fact that both Professor Heymans and I are here today over-represents the number of women by a factor of three.

Carol Monaghan: I was having a look. It is about 30% at almost all levels—

Professor Scaife: And then 13%.

Carol Monaghan: —until it goes to professorial, and then it is 13%.

Professor Scaife: Yes, I think that was in the RAS returns. There is a retention problem, and I would say that gender is at some level the most successful diversity marker. Yes, it is a problem. I agree.

Carol Monaghan: Professor Barstow, do you have anything to add?

Professor Barstow: I would certainly like to add something to that. I feel very strongly about that. We discussed earlier the culture of bullying that can be found. It is absolutely reprehensible that it exists. It is the responsibility of all of us within academia to pay attention to this. It is the responsibility of universities to make sure that they develop working environments that do not create these situations.

Q64 **Carol Monaghan:** Do you think people realise that what they are doing is a form of bullying? I will give you an example. My daughter was at an outreach thing, an engineering thing—I won't say where it was—and one of her friends, another girl who is very good at science, ended up in a different group. They were looking at aeroplane wings. The guy who was leading it was talking about the shape and everything. He turned to her and said, "Of course, you're not going to be interested unless we paint it pink." He thought he was being funny. That is why I am asking. Are people aware of daft comments and the impact of them?

Professor Barstow: There is certainly an element of people not being aware. I think they should be in this modern world. If you are not aware, you are probably missing something somewhere in your personal development and education. If I set that to one side, it is about culture. It is about the idea that we should develop cultures that are accepting of diversity. We are sort of early on the road there. My institution does quite a lot, as do others, I am sure, but there is quite a long way to go before we can say that we are being successful at it. We have done quite well in increasing our gender diversity, but then people leave. Maternity leave gets in the way, particularly for women, and that is not handled very well, I think, by employers of any kind. It is still a problem.

Professor Scaife: I can add to that on that very specific point. For early-career researchers, the cost of childcare is a big issue given the level of salaries at a postdoctoral level.

Professor Barstow: But also the insecurity of being a postdoc at the same time. There are a lot of factors. We could spend probably another hour talking about them. The message is that we have to do it. There is a lot we could do, but it is across the entire system. It is not just a problem for astronomy. It is a problem for HEIs. It is a problem for other workplaces. The space industry is also an area where this needs addressing.

Q65 **Stephen Metcalfe:** Just carrying on from that about improving the diversity, you do that by filling the pipeline at the start and getting more people into it. We heard earlier from Professor Rees about the fact that

kids are interested in two things when they are very young: dinosaurs and space. You cover off potentially both.

Professor Barstow: The dinosaurs are dead.

Carol Monaghan: On this planet.

Stephen Metcalfe: Joking aside, using the extraordinary convening power of astronomy, are there examples that you can point to where it has improved STEM uptake through the work that you or others have been doing, and is there more that we can do to improve that?

Professor Barstow: It is quite hard to get real evidence. I am sure Anna has some good examples from hers. I will quote one from the National Space Centre in Leicester, which we created as a way of trying to develop people's interest in STEM, not just astronomy and space. We have run programmes—I could not give you the detailed evidence right here and now—where we have seen measured improvements in uptake as well as measured improvements in achievement through running certain things, particularly for groups who are not well represented in higher education. There are interventions that we know of that work. The problem is that they are not wide enough. They need to be rolled out more widely than we can deliver.

Q66 **Stephen Metcalfe:** Could you just expand on that a touch with exactly what those are, how we might expand them, and whether that is a resource issue?

Professor Barstow: We run something called the National Space Academy. We reach out across the whole country, and we try to work with teachers to deliver that so that we are having the largest impact that we can. We have been running a space course for A-level-age students in one of our local colleges for a number of years, and that brings in people through less traditional routes, through vocational routes, and helps feed them in. It makes an amazing difference. In fact, I surprisingly found that one of my students came through that route when he graduated this summer. It had really made a difference to him, and it makes a difference to them, but we are talking about 20 students a year. We may be able to run it three times across the country. You can see that the impact would benefit from scaling.

Stephen Metcalfe: Okay, thank you.

Professor Scaife: I certainly do not think that we use astronomy strategically enough in the UK. Certainly, we do not use it as strategically perhaps as other countries have done. If you look at the international collaborations around astronomy, I will highlight the Square Kilometre Array. The SKA, which has an instrument being built in South Africa, was promoted in South Africa as an instrument of economic development, not primarily as a scientific facility. They have built a whole training programme around it that brings students through from school level

through undergraduate through postgraduate and into career paths that target their historically disadvantaged communities.

From the UK, we were able to work with the Newton Fund and ODA funding to widen that programme with South Africa to cover the other African countries of the SKA Africa partnership to develop astronomy training, and that is primarily led by Professor Melvin Hoare at the University of Leeds. That also has a big data/AI aspect because that is a very economically valuable instrument. That has been hugely successful. We were able to do that as part of our international development, and that has benefited the global astronomy community. However, it is much more difficult to do something like that within the UK, ironically.

Q67 **Stephen Metcalfe:** Because?

Professor Scaife: I do not know how you would do it. If you look at the programmatic outreach done by things like the Jodrell Bank Discovery Centre—it has schools programmes and things like that—it has little, if no, public funding. It sits in a very precarious no man's land between different funding routes: between DCMS, what was formerly BEIS and Arts Council England. Because we do not have a well-defined route for the funding for such programmes, we miss out.

Q68 **Stephen Metcalfe:** Thank you. Very lastly, changing tack, going back to the problems you were describing in supporting postdocs and the tenure and the funding around those, do you have any suggestions that you would like to put on the record about how we might resolve that?

Professor Barstow: We need to look at the funding of postdocs. We have some very good schemes like the Ernest Rutherford Fellowships scheme, but they tend to be targeted at people who have done, often, a decade of junior positions. Steve referred to the fact that there is no intermediate step. We lost that a few years ago due to financial constraints imposed by the economic downturn a bit more than a decade ago. That intermediate step really needs to be recreated. There is a yawning gap where people come out with a PhD. If they are lucky, they might get on to a research project, but there is no personal funding that they can apply for to fill that gap.

Q69 **Stephen Metcalfe:** Who makes the decision to make that funding available? Is that the research councils?

Professor Barstow: It will be an STFC thing for astronomy. Historically, it got squeezed out. They have not chosen to recreate it, but that is against the background of the continuous squeeze on funding. Creating the headroom will have been a serious challenge for them.

Stephen Metcalfe: It is about choices.

Professor Barstow: It is about choices, and it is about looking at that gap.

Stephen Metcalfe: Okay. Anna?

Professor Scaife: I completely agree. The lack of a very early-career research fellowship in UK astronomy is a massive gap. It is incredibly damaging. It causes a lot of people to leave the UK and not to establish their career here.

Q70 **Stephen Metcalfe:** And leave the sector as well, or is it just the UK they leave? Do they tend to go into other disciplines?

Professor Scaife: There will be some aspect of that, but if you want to do astronomy, you stay in astronomy. That is the reality.

Chair: Thank you very much, Stephen. Graham Stringer has one final question.

Q71 **Graham Stringer:** As ever, I am always impressed by the enthusiasm of academic scientists. Can you tell us what you think the next major breakthrough will be by British astronomy?

Professor Barstow: British astronomy or international astronomy? Of course, we are parts of international consortia. I would say there would be a strong—

Graham Stringer: Astronomy that Britain is part of.

Professor Barstow: A British role—I have a personal interest, which was mentioned by Katherine, in the Habitable Worlds Observatory, which will be flying out long after I retire. That will be the first instrument to locate and identify an Earth-like planet and demonstrate whether there is life on its surface. To me, that is the outstanding question of our age.

Katherine Fletcher: Just discovering life.

Graham Stringer: Professor Scaife?

Professor Scaife: I would not like to say because what we have seen historically is that what most astronomical facilities are most remembered for are the things that no one predicted. That serendipitous potential for astronomy observatories is something that is very important and that we can all look forward to.

Graham Stringer: Thank you.

Chair: Very good. Thank you very much indeed. Our colleague, Chris Clarkson, points out that Jodrell Bank is not only a very important historical site and very important currently as the headquarters of the Square Kilometre Array but culturally, too. It is where the fourth Doctor Who regenerated into the fifth, I am very reliably informed. To all our witnesses this morning for giving us a terrific start to our inquiry, thank you very much indeed for coming. That concludes this meeting of the Committee.