The spectrum of early career physics

Chao-Hui Feng, Emily Moravec, Tara Nanut, Tomasz Raducha, Orad Reshef, Chandrasekar Sivakumar and LaNell A. Williams

There isn't one single 'early career experience' in physics, and different subfields involve very different opportunities and challenges. Seven early career physicists who work on a range of research topics in different subfields discuss their views on the lessons we can learn from their professional lives.

What is your research about?

Chao-Hui Feng. My research uses hyperspectral imaging and terahertz spectroscopy and imaging to develop new foodstuffs and improve food quality and rapidly detect food safety. My professional goal is to contribute to achieving a sustainable society by addressing the food challenges the world is currently facing, by building a research group that provides knowledge in this field to the wider society.

Emily Moravec. I am a radio astronomer and I investigate the evolution of galaxies that have an actively accreting supermassive black hole that produces jets that are observable in the radio wavelengths. I am particularly interested in studying how these active galaxies evolve when they are gravitationally bound to a group of >100 galaxies.

Tara Nanut. I am an experimental particle physicist, specializing in what we call charm physics — this means physics involving particles containing a c quark. Through it, we can probe many fundamental questions of the Universe, such as the puzzle of matter versus antimatter. I currently conduct my research within the LHCb Collaboration, one of the big experiments at the Large Hadron Collider at CERN.

Tomasz Raducha. My research is about complex socio-technical systems and their dynamics. On the abstract level, I use tools like co-evolving networks, spin-like models or evolutionary games to describe the behaviour of big social groups or evaluate electoral systems on the application level.

Orad Reshef. I work in the field of nanophotonics. We work in the same cleanrooms used in the semiconductor industry and aim to structure nanoscale devices and engineer surfaces with highly customized optical responses. We can flexibly manipulate, detect, reroute or convert photons for applications in imaging, optical sources and lensing, among many others.

Chandrasekar Sivakumar. My research focuses on surface science and nano-technology. I evaluate target systems using experiments and theoretical simulations. The ultimate goal is to study fundamental electron transport at the interface level in nanoscale devices. To do so, I use the ultra-high-vacuum scanning probe micro-scope (UHV-SPM) for experiments and the density functional theory–Vienna Ab initio Simulation Package (DFT-VASP) and mole-cular dynamics programs for simulations of atomic and molecular level systems.

LaNell A. Williams. My current research is in soft condensed matter and biophysics, and focuses on understanding the self-assembly of RNA viruses such as bacteriophage MS2. The goal of the project is to see what viruses can teach us about the physics behind self-assembly.

What does your field do well to support early career researchers?

LaNell A. Williams. Soft condensed matter in general is a new field in comparison with some of the other fields of physics. As a result, the field naturally fosters a general curiosity about science that doesn't breed extreme competition in the same way other fields might. There is more of an emphasis on doing good science without the added pressure that someone might 'scoop' your idea or paper. The field is just too vast! There are too many systems that fall under the soft condensed matter umbrella for any large number of people to have the same ideas. The interdisciplinary research that is available underneath the soft condensed matter umbrella, such as biophysics, allows us to learn from other scientists in different fields and gain many perspectives on our work. These factors make the field fun and take pressure off early career researchers (ECRs).

Tomasz Raducha. I think ECRs in physics of complex systems are generally encouraged to participate in supplementary activities that improve their soft skills. It's normal to go for a conference each year or take part in a workshop, an outreach event or some kind of scientific exchange. In some fields, those activities are considered unnecessary, as they don't directly and immediately improve the research quality produced by an ECR. All of them, however, can hugely improve communication skills, the ability to work and collaborate with groups of people and they force ECRs to think about the bigger context of their research, all of which is highly valuable in a long-term scientific career. In my opinion, the community of physicists in complex systems understands that and encourages ECRs to use such opportunities. I am aware that it depends also on the supervisor, but, in my own experience, collaborations and exchanges are frequently promoted, as well as public speaking — this one especially is an inherent part of doing science these days.

Orad Reshef. In photonics, our professional societies do a particularly good job of enabling authentic networking opportunities for ECRs. For example, in the Optical Society (the OSA), ECRs can volunteer to help run technical groups for specific topics, such as the Nanophotonics technical group or the Integrated Photonics technical group. These groups are mini-communities that preserve a start-up feel within the larger organization, and they are able to host their own events focused on their subtopic. It's very easy to get involved in a technical group,

and, in my experience, the members quickly start to recognize the names of relatively young researchers in their subfield as they get more and more involved.

Tara Nanut. One cannot escape the fact that experimental particle physics usually entails working in a large collaboration of hundreds, if not thousands, of people. This community structure has a large impact on work organization and the professional life of an ECR.

One positive aspect is that it gives an opportunity for structured groups that are readily accessible to all members. Almost all larger collaborations now have a dedicated group of early career representatives. Though the structure of these groups differs, common activities include organizing and/or promoting workshops on various topics (including work-related, career-related, soft skills and mental health), mentoring programmes, gatherings among ECRs and/or senior colleagues, and monitoring the well-being of ECRs and collecting ideas for further activities. These activities are steadily gaining momentum. In several cases, the representative groups of various experiments are now joining forces to create joint events and programmes, as well as sharing information, experience and ideas.

Another definite plus of large experiments is that job positions on member institutes are advertised through collaboration-wide mailing lists, and sometimes even in other collaborations.

Chandrasekar Sivakumar. In my experience, universities have formed committees to guide ECRs at all levels by providing a comfortable workspace with laboratory resources, instructions for conducting and reporting research work with integrity under the code of conduct for research ethics and guidance for applying for and procuring grants from various sources. Strong collaboration in science, technology, engineering, mathematics and medicine (STEMM) is encouraged at the institutional level, and progressing ECRs are acknowledged.

In addition, several scientific societies support ECRs, a couple of which I am closely associated with. The Physical Society of Taiwan (TPS) acknowledges ECRs by involving them in policy-making committees and encourages emerging researchers at their annual meeting. The American Physical Society (APS) offers several forums for addressing and discussing issues related to ECRs. The APS Industry Mentoring for Physicists (IMPact) programme pairs students and ECRs with industrial physicists to provide career guidance and develop non-technical skills to navigate challenges. These societies also support ECRs to engage in public policy-making and governance in STEMM education.

Emily Moravec. I would say that professional societies such as the American Astronomical Society and the European Astronomical Society do a good job of providing a range of workshops, sessions and opportunities at annual conferences for ECRs, on topics such as professional development, applying for jobs, soft skills, networking, careers outside astronomy, mental health, coding/Python and public outreach. Additionally, various subfields of astronomy host conferences that are meant solely for ECRs to meet one another and learn about one another's work. Relatedly, some conferences explicitly encourage early career submissions.

The astronomical community has begun to discuss and bring to attention issues that limit the advancement of women, LGBT+ people and minority communities in our

The contributors

Chao-Hui Feng
Chao-Hui Feng has expertise in estimating meat quality by using hyperspectral imaging and terahertz spectroscopy, modifying natural hog casing by using surfactant solution and lactic acid, and applying an innovative cooling method (immersion vacuum cooling) to meat products. She has been invited as Guest Associate Editor for *Frontiers in Plant Science*, the Editor for the upcoming publication *The Book of Flavonoids*, obtained 39 awards and 12 patents.

Emily Moravec
Emily Moravec is a postdoctoral researcher at the Astronomical Institute of the Czech Academy of Sciences and a support scientist at the Czech node of the European ALMA Regional Centre. She received a B.A. from St. Olaf College in 2014 with a major in Physics and a M.S. and Ph.D. from the University of Florida in 2019 in Astronomy. In 2020, she moved internationally to start her first postdoc in Prague, Czech Republic and will be starting her second postdoc at Green Bank Observatory in West Virginia, USA in November 2021. Dr. Moravec is a radio astronomer who investigates the evolution of active galaxies. Her specific research interests are active galactic nuclei, radio galaxies, galaxy clusters and radio interferometry. Beyond research, Dr. Moravec is interested in science policy and providing early career scientists with resources to succeed in the field.

Tara Nanut
Tara Nanut completed her studies at the University of Ljubljana. Her graduate work was done in the scope of the Belle and Belle II Collaborations in Japan. Afterwards, she moved to the École Polytechnique Fédérale de Lausanne in Switzerland, where she conducts research within the LHCb Collaboration at CERN.

Tomasz Raducha
Tomasz Raducha is a postdoctoral researcher at the Institute for Cross-Disciplinary Physics and Complex Systems in Spain investigating complex adaptive systems. He obtained a Ph.D. in Physics from the University of Warsaw in Poland. Currently, he is a member of the CSS Council, steering committee of the WWCS and a former member of the advisory board of the yrCSS.

Orad Reshef
Orad Reshef is a research associate working with Professor Robert W. Boyd at the University of Ottawa and the co-founder of Brilliant Nanophotonics Inc. He has recently been selected as a member of the 2021 class of OSA Ambassadors.

Chandrasekar Sivakumar
Chandrasekar Sivakumar received his Masters in Physics from SRMV College of Arts and Science affiliated to Bharathiar University, Coimbatore, India. He is currently a Ph.D. candidate in the Department of Physics at National Chung Hsing University, Taiwan. He is an elected member of the executive committee of the student chapter in the Physical Society of Taiwan and a student ambassador of the American Physical Society.

LaNell A. Williams
LaNell A. Williams is a Ph.D. student at Harvard University studying soft condensed matter physics. Born and raised in Memphis, TN, LaNell graduated with her B.A. in Physics at Wesleyan University and went on to receive her M.A. from Fisk University. She is a member of the Equity and Inclusion Committee in Harvard's Department of Physics. As the founding member and chair of the Society of Underrepresented Students in STEM, she passionately advocates for creating meaningful resources to support under-represented researchers in pursuit of physics. She is also the co-founder of the Women+ of Color Project (WOCP), an initiative geared towards providing women of colour with resources on graduate school. In 2020, she was elected as Councillor of the Forum on Graduate Student Affairs (FGSA) and the Forum on Early Careers (FECS) and also joined the APS-IDEA steering committee.

field. Though the culture is beginning to change in this regard, the astronomical community needs to do a lot more to fully and fairly integrate these groups into the profession.

In my experience, astronomers of all stages are generally quite friendly, willing to discuss their work with anyone and willing to collaborate with and help ECRs.

Chao-Hui Feng. In my experience, many individuals have been supportive. I have been encouraged by my supervisors from different stages, such as my postgraduate supervisor, who inspired me to go aboard to broaden my horizon, and my Ph.D. supervisor, who gave me the opportunity to pursue a Ph.D. degree. When I was in the dark and depressing period of my research work, the postdoctoral researchers in my group offered guidance, assistance and encouragement. Similarly, my postdoctoral supervisors provided me with the opportunity to learn new technologies to make my research more innovative.

What could be better for ECRs?

Emily Moravec. A group of approximately 50 early career astronomers produced a white paper[1] on the ECR perspective on the coming decade of research, which I was involved with writing. The recommendations of the white paper include some that could apply to any field of physics and others that are more astrophysics-specific. Those that are more general include: for each institution to have mentoring programmes for graduate students and postdocs; funding agencies to encourage 4–5-year postdoctoral appointments and discourage those shorter than 3 years; postdoctoral appointments to cover relocation costs; to establish a list of best practices for parental leave policies for graduate students and postdocs; to require training on gender and racial harassment for all members of academic departments; to de-emphasize GRE scores in graduate school applications; and departments to offer regular opportunities to learn about non-academic careers. Those that are more astronomy-specific include: a restructuring of graduate curricula to teach computational and statistical techniques and coding best practices needed for the big data era; all telescope proposal and conference talk application processes should be anonymous; and more astronomical journals should detail contributions to papers in a specific way (important in a field where long author lists are common).

Tara Nanut. I would say that the largest issue for ECRs in general is the precarious nature of short-term contracts. A large chunk of an ECRs professional life is taken up by worries about securing the next — and, eventually, a permanent — position. I don't presume to have an answer on how to create the best environment for ECRs within these conditions, but I can highlight a practice I admire: the initiative of the theoretical high energy physics community to commit to common deadlines for postdoc offers. The initiative is based on the premise that enabling young scientists to have a fair and free choice among job opportunities is not only good in its own right but also beneficial for the field as a whole in the long run. By contrast, I can vouch from personal experience that situations where one must accept or turn down a position before knowing the outcome of other applications are common and extremely stressful. Similar practices for coordinating offer deadlines have been reported by the American Mathematical Society. I think this is something that, while probably hard to implement in a large field, would be a huge success for better conditions for ECRs.

Orad Reshef. The job market is frustrating to navigate. Most students pursue a Ph.D. because they're under the impression that higher education provides more (and more lucrative) career opportunities. On some level, this is true; however, the reality of the situation is that it's hard to find an interesting, well-paying job in every city, and moving gets tiring, especially for those who have a family. Additionally, most mentors at a university, such as Ph.D. advisers, are accustomed to directing ECRs towards academia, where the funnel gets smaller and smaller and there are few opportunities. Professional societies try to improve on this with online job portals, but these systems, overall, are still inefficient.

Chandrasekar Sivakumar. Academic publishing is one of the most important aspects of an ECR's career. However, many ECRs either lack the ability to assess the quality of a journal or are unfamiliar with the terminology and processes used in academic publishing. As a result, recent figures suggest that predatory journals have been using (or misusing) ECRs as peer reviewers and editorial board members[2]. Here are a few important things that every ECR should be familiar with: indexing (Web of Science, Scopus, PubMed, DOAJ and so on), quartile ranking (Q1–Q4) with other citation metrics (such as JCR Impact Factor, Immediacy Index, CiteScore), plagiarism and predatory journals with unethical publishing. From learning about these, ECRs will eventually develop knowledge on how to identify legitimate and predatory publishers, as well as how to evaluate a journal. In addition, ECRs should stay updated on the Committee on Publication Ethics (COPE), a body mandated with formulating ethical research standards and assisting researchers and publishers in maintaining ethical practice as a foundational element of publishing culture.

Tomasz Raducha. A very specific problem of ECRs in physics of complex systems is that other physicists don't always fully recognize the field. It seems to me that many, especially senior, physicists understand physics as the science of inanimate matter exclusively, and, for some reason, vehemently defend it from including more interdisciplinary topics. I personally was asked during a grant interview why I submitted the grant proposal in the physics track, not computer sciences or something else (and it was submitted as physics of complex systems). In the end, I obtained the grant, but explaining the connection of one's research with traditional physics can be annoying, if done too frequently. Moreover, currently, most valuable research is highly interdisciplinary, even more so in complex systems, where many projects include collaboration among scientists from several fields. To which field should the project be assigned? Fortunately, there are more and more institutes and departments of physics of complex systems being established. But, in my experience, the issue remains. I think it's more specific to ECRs, because they have to explain themselves more often than senior scientists with a permanent position and a high h-index.

LaNell A. Williams. Soft condensed matter physics could do more to inspire and recruit students to the field at an earlier stage. I often find undergraduate students who are unaware they could study other systems using physics — like viruses! If we could incorporate more examples of soft condensed matter in our earlier curriculum, that would make a huge difference in expanding the idea of what physicists can study.

Chao-Hui Feng. Starting research is difficult, as we don't know how the research could be done. In this case, it is very helpful

if someone (either a supervisor or the experienced senior researchers) guides the ECRs to establish their research work. Conversely, in my current situation, all the experimental lab set-up, teaching and supervision, research funding securing and project management should be managed by myself as a research leader. Although it is a big challenge, I always believe that "where there is a will, there is a way".

What advice would you give other ECRs?

Chao-Hui Feng. Never give up on your science career. There will be thousands of challenges and difficulties, but continuously advocate for your work, seek different ways and discuss with other researchers within or outside of your field, who may inspire you to find the way to solve problems. For example, before I went to Japan, I did not speak Japanese or know much about hyperspectral imaging technology. However, I read a lot of relevant papers to understand the principle of the technology and actively consulted the experts online or via other means. Also, I studied Japanese very hard to be able to communicate and to promote my research.

If there is any chance, I also recommend you work with experts from other fields to get a broader horizon. For instance, during my Ph.D. study, I collaborated with technicians and scientists who are not in my fields. I believe that I could not reach my present stage without the expertise, knowledge and guidance from those extraordinary scientists. It is my great fortune to work with those people who always support me. The collaborations also gave me good experiences in connecting my own research work to multidisciplinary research.

Tomasz Raducha. It's important to try working on different topics and with different people. I once heard the advice that it's better to stick to one subject for a long time to increase the chances of obtaining a permanent position. As much as this can be true, I don't think obtaining a permanent position should be considered the main goal of ECRs. It's more important to perform research that we find interesting and look for problems that inspire us. I've seen young researchers already burnt out, because of sticking to subjects that they didn't really like. There is a huge number of subfields and unsolved issues to choose from; try something that you really find fascinating! Of course, ECRs don't have full freedom to perform the research they want, but they can think about it when changing positions or look for side projects in collaboration with other motivated young researchers. Finally, trying your hand in different areas gives you a better overview of the field and the broader experience allows you to contribute to many projects and fit in more positions. Then, you increase your chances of finding an inspiring one.

Emily Moravec. For ECRs in astronomy and astrophysics, I advise knowing Python well, learning about Python environments and having a Python environment for each project you work on, so that your results and plots are easily reproducible. Get comfortable with Git and use it — and remember to regularly back up your scripts and data!

I also advise intentionally pursuing a work–life balance, talking to others at your career stage about its pressures and paying attention to mental health and talking about it.

Finally, make a website to promote your work. Go to conferences and intentionally seek out colleagues in your specific area of research that you don't know or would like to reconnect with and ask questions — I have learned about, gotten jobs from and written papers with connections made at conferences. This is also where new ideas often come from. You should also find a mentor who is not your adviser.

LaNell A. Williams. My advice to other Ph.D. students would be to join research labs as soon as possible! Be very strategic about who you choose to be your adviser and always ask questions. I learned many 'unwritten rules' later on in my Ph.D. that I could have known sooner had I just asked!

Tara Nanut. First, whenever you are new to something, don't be afraid to ask questions. There are too many stories that have involved the line "I don't dare to ask, they probably expect me to know this", followed by arbitrary many iterations of "I really should have asked earlier, now I feel even more uncomfortable".

Second, the recommendations of your supervisors have a huge weight in your future career. This includes the supervisor at your local institute, as well as group leaders of mixed-institutes groups where you are active. The connections of your supervisor can also play a crucial role, especially if they are willing to take an active stance in pushing you forward. So, keep this in mind, and don't be too shy!

Chandrasekar Sivakumar. ECRs should recognize the value of visibility and improve it, where the outcome triggers the Matthew effect (that 'the rich get richer'). You can take credit for evaluating a paper as a reviewer and handling articles in the journal as editors on Publons (a platform for global researchers to maintain and track their research portfolio and share with peers). In addition, Publons identifies and recognizes the top researchers based on citations, review contributions and editorial contributions.

A revolution may occur in academic publishing as a result of several concerns that have been raised over the years. The copyright of the published content and openness (in terms of open access and open research) are two such critical issues. Unless ECRs are aware of academic publishing ethics and standards, finding a solution for the evolving issues is impossible.

Finally, I encourage involvement in public affairs and media outlets. Many researchers won't take it seriously, but I highly recommended that they practice engaging with the media and the general public.

Orad Reshef. ECRs need an online presence: get on social media now and spend a weekend putting up a portfolio website. My activity on Twitter has opened up so many opportunities for me — invited talks, conference participation, job interviews and so on. It's the easiest way to become a known quantity within the academic community, and, at the end of the day, your reputation within your field's community is the only thing that matters when it comes to advancing your career.

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