

A Letter to HEP-TH Postgraduates on Career Prospects

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Introduction

This is a public letter to postgraduates in the field of theoretical high energy physics about career prospects in both academia and “industry”. This letter contains

- my personal experiences in job hunting as a penultimate year student in theoretical physics,
- some statistics about the career paths of past postgraduates from the Centre for Particle Theory (CPT) in the department of mathematics of the Durham University,
- thoughts and opinions on academic and industrial career options,
- tips and tricks in applying for jobs out of academia,
- further resources for various related topics in the bibliography.

My experience inspired my supervisor to take the recent initiative in the department to build an alumni network and improve career support for postgraduates. This letter should accompany well with the new initiative, and gave a taste why it was proposed in the first place.

I am writing out my personal experience in brutal honesty, in the hope that people would be less likely to fall into a worse situation than mine. All opinions are mine, which are inherently biased. I might have not formed some of my thoughts if I had a more “successful” academic career. I aim to provide an alternative perspective than those voices that have always been in the academia their entire lives. It should serve as a reality check for young aspiring physicists like I was before. This is also quite important as I feel there is a great fear for people to admit “defeat” in academia. It almost became a kind of co-dependency, where I felt I could not live without academia. I apologise in advance for any discomfort some may feel.

I have only recently passed my PhD examination after some “major” corrections on *background* materials in my [thesis](#), before which I had struggled for almost a year to land *any* job at all regardless of industries. I had been an “objectively” mediocre postgraduate, who was roasted by some basic questions on Feynmann diagrams during my viva. I only have one publication, and one “forthcoming” paper waiting for my supervisor’s final touches. If you think you are doing better than me, then you might already be in a less dire situation.

Job Hunting Experience

I entered the PhD programme at Durham in 2018. After the first year of taught courses, I had been doing research on twisted indices of three-dimensional gauge theories. I spent a year to complete all the computations for my first paper. For the rest of my PhD I had been working on a few different projects, the fruit from one of which is hopefully going to be published soon™.

I only started preparing for postdoc applications in October 2021. I was very under-prepared completely due to my own ignorance. I knew I was not competitive with only a single paper. But it is my childhood dream to be a physicist. So I had to give it a try. The first challenge was to obtain two additional reference letters other than my supervisor's, ideally from faculty members in other institutes. However I had not had any chance to attend any conferences due to the pandemic. I had zero contacts outside of my department. Even my co-author declined to provide a letter because we did not have much discussions. Fortunately some kind souls in the department agreed to provide such letters. I applied to a dozen places. But realistically there were about three places where I had a decent chance. Those were the places that have a faculty member doing research *very* close to mine. I got short-listed for two, but rejected for both.

This entire process of my postdoc application lasted from October 2021 to May 2022. I was checking the [HEP Theory Postdoc Rumor Mill](#) on a daily basis. It was a soul-crushingly painful experience. The hope of getting any offer became exponentially lower every single day after the [common deadline](#) of January the 7th. I had to start looking for other career options. I was waking up every morning to look through every job boards for any opportunities. There was a time when I thought I was the most incompetent human being ever. I spent 10 years studying arguably the deepest and the most successful theory in human knowledge, only to find out I was not even being hired for a temporary, low paying contract job. I had this fantasy of being offered a postdoc, so I could finally end this misery.

I was not the most productive postgraduate in the field. The excellent postgraduate researchers on the other continent usually publish 4 to 10 times more than us. My social skills are not so great either. But I had to stop blaming myself at some point. It took me a long time to realise that

- my research area was not trendy;
- my research group had no one else working on similar topics;
- my institute was not the most prestigious [1, 2];
- I was not from the most privileged group [3] in terms of social inclusion.

The job hunting in industry was a rough ride as well. Due to the practical uselessness of our field, there are little interests from employers in hiring a PhD in theoretical physics. My only other selling point was my programming skills. I was a competent programmer, at least by scientists' standard. As my PhD project didn't have any programming component other than Mathematica, I had been consciously putting out some hobby projects for employability reasons. However that did not seem to help much. Out of the 100 or more job applications I submitted, I had been interviewed by only four companies. My semi-successful one was an internship opportunity as a data scientist at Tesco, for which I did my first real data science project and made into the final round. But I was rejected due to my lack of experience after all. It would have been much easier if I did a PhD in analysing the LHC data. Since then I had been studying more programming, more statistics, more data science, more machine learning, and some finance for various potential job opportunities. My job hunting finally ended after I got an offer in September to be a "quantitative developer" at a small finance company in London. I was lucky enough to not be unemployed after graduation. Otherwise I could have been starving during this winter.

Career Prospects

You might say I was just calling sour grapes because I was not one of those lucky bastards who got a postdoc. I would have to agree to some point. But I am far from the only one with a similar experience. Due to my desperation to get a job and my emotional need to get some excuses, I looked up every PhD graduates from our group since 2010, and reached out to everyone I could find. Some kind people offered their wisdom to me, which helped me immensely. I also made a little diagram in Figure 1 to show what the past PhD graduates from the Centre for Particle Theory have been doing. The diagram was made in May 2022. I was only able to find out for 43 out of the 67 graduates. But the missing portion is very unlikely to be working in academia.

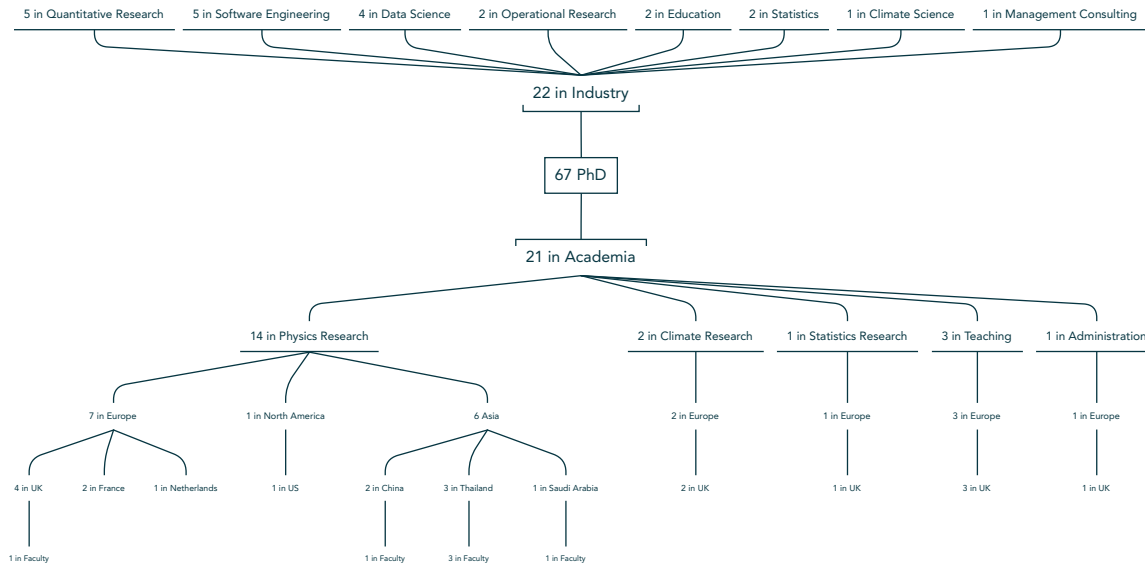


Figure 1. Career Statistics of PhD Students from CPT since 2010

I was quite shocked to learn that only one was able to land a faculty job in the western world. If I look closely what are the common traits for people hired at permanent academic posts, it is not hard to see the “law of downward flow” [2]. The Institute of Alice hiring graduates from the Institute of Bob is the “sincerest” way for Alice to affirm the academic excellence of Bob. However this affirmation is almost never mutual, which gives a strong hierarchy in the faculty hiring network. Unfortunately from this perspective, not many institutes seem to be happy about the academic quality of Durham.

Academia

A typical path for us to land a permanent job (tenure) in academia is to grind through 3 to 5 postdocs, which would burn through most of our remaining years as *young* scientists. However, this path requires both an extraordinary amount of hard-work and good-luck. According to the statistics from the [joint postdoc applications related to theories on the unification of fundamental interactions](#), roughly 30% of postdoc applications are successful each year. This includes fresh graduates and postdoc veterans. The cumulative success rate to get 4 postdocs is then about 0.81%. I do not have statistics about the success rate of tenure applications. But it is not likely to be much higher than 1%.

To me this does not sound like a great career choice, unless you have strong financial backup options. If someone is training to be a medical doctor, and being competent at their chops, then

I would expect them to have a non-negligible chance of being hired as a medical doctor. Even a successful hep-th career would involve constantly moving around the globe with abysmal pay and little stability for many years. The salary of a postdoc may really struggle in a lot of places under the current crisis of cost of living. I don't think these are the best conditions for physicists to do research. Some people believe [4] this is one reason the subject has been intellectually stagnant during the last 40 years.

I think this is well known among the senior faculties in our field. But it is rarely communicated directly with PhD students. There might be some conflicts of interests since it is important to keep the flow from the young generations into the field.

Industry

I believe that no one in a theoretical physics PhD programme chose the path to not become a theoretical physicist. I have not heard anyone saying they are doing a PhD in theoretical physics with the aim to become a quant. It is quite unlikely any PhD programme in theoretical physics is designed to have any training on practical skills demanded in industry either. Our field is entirely isolated from any industries. I think PhD graduates in our field are in the most unfortunate situation. The only place they are immediately useful is in hep-th research. But this place is not hiring nearly enough people. So we have no choice but to abandon our original mission of being a sacrifice to science.

Physics is really really nice. But it is also quite nice to be able to afford nice things, such as heating my home. From the statistics shown in Figure 1, a significant proportion of theoretical physics PhD graduates entered the financial and technological industries. The most common roles from my experience are quantitative researchers in investment banks or hedge funds, software engineers in the finance sector, and data scientists in various industries. In these industries, nobody is sacrificing themselves in the name of "science". People all understand they are working for the money.

Quantitative researchers are commonly referred to as "quants". They are the mathematical researchers in finance, responsible for generating "alphas", signals for profitable trades, from mathematical models. Most of them are PhD holders, ranging from mathematics, statistics, physics, and computer science. Typically quants are organised in a similar way as research groups in academia. This career path is perhaps the most rewarding one in terms of compensations. It is typical for a starting role to earn more than double the amount of a full professor in physics. Theoretical physicists were once the largest group of people being hired for this role [5]. However, it has become more difficult for us to enter this industry, as the dedicated master's degree of financial engineering becomes more popular in the recent years.

Software engineers (SWE) are of course the cool "hackers". The compensations for software engineers vary wildly in different industries. It is very difficult for a theoretical physicist to compete in this field in terms of pure engineering capabilities. Therefore software engineers from our background usually don't have as large compensations. However, we are often hired as *competent* programmers who also understand more mathematics than a typical software engineer. In finance these are the role of "quantitative developers", which is a hybrid between quants and software engineers. The financial sector pays the most handsomely as we may expect.

Data scientists are people who utilise machine learning models to extract information from large data sets. They are machine learning practitioners. For example a data scientist at Tesco might analyse a large database of its retail stores and build a model to predict the profitability of proposed new stores. These jobs typically don't require a PhD degree. Theoretical physicists are usually not the best candidates as data scientists as we typically rely on "big brain" rather than "big data". Astrophysicists and collider physicists have a much better time competing in this space.

An alternative route worth considering is to become a machine learning researcher. I learned a lot about this from a fellow string theorist turned machine learning researcher. This involves reading machine learning papers from arxiv and applying them to business problems. The space is less saturated than data science, usually with better compensations. It is almost impossible to compete with PhD holders from machine learning, especially in those big tech companies. But the demand for a capable researcher in machine learning is still high in other places where the “best” would not consider.

Advice on Job Applications in Industry

I have tried to prepare for interviewing for all of the above roles, which was a very daunting task to do in a short period of time. The one redeeming quality is that these roles actually all share a common pool of skills including:

- programming in Python (or less commonly in C++),
- probability and statistics,
- data preparation and machine learning.

Albeit different roles have different emphasis on some of the skills.

It is very important to do thorough research on the interview processes for each of these roles, which typically include the following parts:

- An algorithmic style coding interview popularised by Google. This can be prepared for with a lot of practices from free resources like [neetCode](#). This part is almost always at the screening phase for all these roles. It is not really all that relevant for the day-to-day jobs. But it is an economical way for employers to filter out a large proportion of applicants.
- A brain teaser session for quantitative researchers, which can be prepared from dedicated interview books like *Heard on the Street* [6].
- A test on a data-driven project for quantitative researchers and data scientists, which can be prepared with textbooks like *The Elements of Statistical Learning* [7] and free resources on [Kaggle](#).

With some luck and persistence, these skills should be sufficient to provide a much-more-than-negligible chance to be hired for these jobs.

The interview can last anywhere between three to six rounds with various interviewers ranging from employees in the same role, team leads, and managers. Some companies would also arrange a full day on-site interview to roast you from all angles they may deem appropriate. From the perspective of employers, it is very expensive to hire a wrong person. So they would rather mistakenly filter out some good candidates than letting any “bad apples” in. The interview preparation could easily take many months to be done thoroughly. Therefore it is advantageous to start early.

It is quite common for companies to “ignore” the job applications. If there are certain roles and companies which are of strong interests, then it is worth trying to get in touch with a team member for an informal chat. Simply cold emailing them is not actually a bad idea.

For people who are interested in the career of quants, there is an area of related mathematics called stochastic calculus, which is deeply connected with quantum field theories. The path integral interpretation of stochastic calculus is very close to the path integral of euclidean quantum mechanics. In fact one of the key formulae, the [Feynman-Kac formula](#), was co-developed by

Feynman. It could be advantageous if what we did in the PhD research can be linked with fields related to the job.

There are a lot of head hunters in the finance and technology sectors, who would get paid for their client companies if you are hired through them. Their pay is usually a percentage of your first year's salary. They should be responsible for guiding you through the application and interview process. In my experience most of them are completely useless. I have only seen one decently responsible and knowledgeable head hunter out of the dozen that contacted me.

There are some deadly "traps" to be wary of in the data science industry. Some companies like [Kubrick](#) offer to train you while giving you a respectable salary, on the condition that you must work for their clients for some fixed number of years. You would not be able to refuse to be deployed to some corners of the country where their clients are based. In breaking the contract, you would be liable of paying a huge amount of "training" fees. The training is usually of mediocre quality which can be obtained easily from YouTube, while the fees are at the level of university tuition fees.

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