COSMO '09: Where the Subatomic Meets the Extragalactic

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Countdown

Over the winter break of late 2008, I and many other physics majors across the nation applied for summer Research Experience for Undergraduates (REU) positions at various universities across the United States and abroad. When the happy day finally came, bearing news of my acceptance to a program at University College London, I set immediately to planning out what I should be doing. I was given the extraordinary opportunity to be overseas for the summer, so in addition to doing research I wanted to investigate what academic conferences were going on in England and continental Europe.

I didn't know where to begin, but my old cosmology textbook was on my desk. I had noted earlier that the author was English and, perhaps, doing some research on him could shed some light on what conferences were going on in the area. A few seconds of searching led me to two conferences: one at the University of Portsmouth and the other at the illustrious and world famous research institution, the European Center for Nuclear Research (CERN).

Upon arrival at University College London, I was immediately thrust into the world of hard research. I had done research before at my institution, Western Washington University, but that was more guided and directed by my advisor. My summer adivsor had to leave for a family emergency in my first week, so I stayed afloat by powering through the research papers I was given and trying to figure out how to understand a new computer language. Scheduling had forced me to scrap the Portsmouth conference from my itinerary, but I continued on with the intellectual challenges.

After about three months of frustration and success, the time for the CERN conference was nudging ever closer. I wanted to go, but bring something more than just my audio recorder. In the last few days of my research program in London, I frantically and exhaustingly rendered a poster to present at CERN.

Geneva would prove to be a linguistic challenge, but a scientific and artistic sanctuary.

In the time leading up to the conference, I had been monitoring what the schedule was and how to plan mine accordingly. Earlier in the year I had attended and reported on the April meeting of the American Physical Society.

There, I had taken in my fill of dark matter research, so I decided to plan my schedule this time around my other research interest that I didn't know as much about: dark energy.

The conference was structured around the theme of particle physics and cosmology, both two huge, over-arching fields in physics and astronomy. The orders of magnitude with respect to size scales that separated one talk from another could have 60 zeroes between them. The difference between the quantum scale of 0.0(add thirty one zeroes)1 meters, versus the cosmological scale of 1(and twenty five zeroes) meters offered an immediate intellectual challenge of just trying to comprehend how fantastically small or frighteningly huge the topics in question were.

Only weeks before the conference was due to begin, the affiliated website stated that none other than Stephen Hawking would be in attendance at the conference. I felt I had hit the proverbial jackpot for interviews if I could even get close to him, let alone even see him in the auditorium.

Arrival

This being the first academic conference I had been to in another country, I unknowingly found myself completely unprepared for a massive language barrier. The conference was located at CERN's main facility in Geneva, Switzerland, right on the border with France. I had naïvely assumed that the country would be very accessible to English-only speakers, but was proved wrong within minutes of coming out the other side of customs. After missing the necessary bus twice due to language barriers, I eventually found my way to my hotel just across the border in Ferney, France, the former home to satirist Voltaire. In a seemingly complete

The quiet town of Ferney, just across the Franco-Swiss border.

reversal of language stereotype, the French side seemed more understanding and accepting of English than the Swiss side.

Language barriers and a night of rest aside, my arrival at the CERN main campus filled me with an unforgettable awe and wonder, accentuated further by the Lord of the Rings soundtrack I was listening to at the time. The institution I had read and studied so much about in the past few years was finally in my sight.

A group of attendees picked up our official ID badges at the reception desk and proceeded down the halls to find the main auditorium. While navigating the labyrinth of offices that surrounded our conference's main venue, I took note of my surroundings. I had been to NASA's Jet Propulsion Laboratory a year ago and only imagined that CERN would be ten times as high tech, judging from the pictures of extremely complex particle accelerator equipment I've seen in magazines. CERN, like many other particle accelerator laboratories, is an organization and an institution. It houses the Large Hadron Collider (LHC). While the instruments inside the gargantuan underground ring may change, CERN will always be there to administer it. I was taken aback to see offices reminiscent of those built in the late 1970's and early 1980's, half-expecting to see futuristic robots meandering the halls. But, the institution has been around for far longer than the LHC instrument itself. All the high-tech business takes place underground at CERN, far removed from the auditorium in which we had just arrived. Curiously the auditorium had remnants of a translator booth and dials so that you could change the language of the words coming through your headset (not available for this conference).

The structure of the talks and venue was entirely different from the large, national meeting I had attended earlier in the year. While at the APS meeting, many talks and sessions were going on parallel to one another with upwards of thousands in attendance. This small conference of some 350 people had nearly all the sessions going on one after another in a single lecture hall. The associated coffee and lunch breaks made for a very social atmosphere, but also an extremely intimidating one. It wasn't that the people at the conference themselves were intimidating, but being probably the only undergraduate at such a conference made me feel like I was way out of my league.

CERN's open and airy campus detracts from the fact that some of the buildings feel antique.

The Small…

The only exposure I had to String Theory before COSMO '09 was through Brian Greene, a physicist and string theorist most famous for his bestselling popular physics book on String Theory, The Elegant Universe. Most branches of physics agrees with other branches, like certain phenomenon on the macroscopic scale being derived out of quantum mechanics, for example. However, some parts don't mesh so well. Trying to get gravity to work on the quantum scale is seemingly impossible with current physics, so String Theory and its competitors seek to bridge the gap to help make a "theory of everything". Under such a thing, virtually all of physics could be derived from all other branches, making it entirely coherent and self-sufficient. String Theory isn't without its share of vociferous critics, however. Many physicists claim that String Theory hasn't produced anything of note in the past couple of decades and the outlook doesn't look too promising either.

In order to get a feel for the field myself, I decided to attend the plenary session on String Cosmology at the conference. The field is essentially applying the workings of String Theory, which would normally operate on the unimaginably tiny size scales that make atoms look like solar systems, to the field of cosmology: the study of the history and evolution of the universe.

Needless to say, the complexity of the talks absolutely dwarfed anything I have ever been exposed to in my academic career to date, including my Introduction to Electrodynamics class. After the talks, I was more confused than I had been when I entered. The jumbled array of derivatives, integrals within integrals and symbols I had never seen before warranted me to sit down and have a less formal discussion about String Theory.

I sat and talked with Dr. Ruth Gregory, who teaches in both the mathematics and physics departments at Durham University in England and who gave a talk on string cosmology at COSMO ’09. I asked Dr. Gregory if String Theory is *all* math.

“It's pretty mathematical, yes. Or rather, there's a lot of quite high powered mathematics used in an awful lot of string theory. Now I'm not a string theorist, I do more of gravitational physics, but obviously since string theory claims to be a theory of quantum gravity, I do find myself working around the edges of it, particularly when it comes to gravity. So, yeah it is quite mathematical.”

Although my interests are largely cosmological, many in my age group that have been exposed to the popularization of String Theory via Brian Greene do have a big interest in the field and desperately want to study things more advanced than popular science books. However, jumping into a graduate textbook on scalar fields isn’t the best approach.

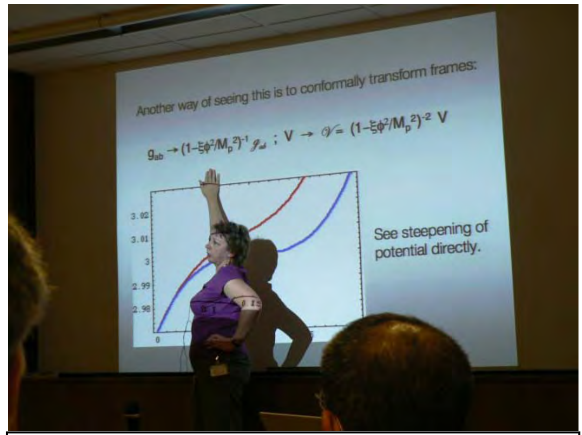
“I wouldn’t recommend just diving into maths, either,” she said, “because if you were just digging into maths you wouldn't necessarily know why you were doing it. It's an interesting point you raise, because I'm not sure there are any books or articles that are intermediate. You got by with the popular book where something is really highly technical, and I was thinking if there was anything in the middle and I just can't think of anything actually.”

One topic that is semi-related to String Theory is called the Braneworld Theory. In it, extra dimensions can be represented as shower curtain-like membranes wherein spacetime resides. The creation of new universes can happen when two or more of these spacetime shower curtains collide. Less popularized than String Theory, but still popular among budding physicists like myself, I asked if that was anything as math-intensive as String Theory.

“It's probably less math intensive than string theory. It depends, if you sat down and talked to a string theorist they would be able to make certain concepts reasonably understandable without having to get into too much mathematics, but with braneworlds, the level of maths that you use there, it's not as high powered as many of the ideas of string theory. It's still quite technical because you're assuming people have a working knowledge of general relativity, but if you have a working knowledge of general relativity, then you could can actually come to grips with braneworlds fairly straightforwardly, whereas with string theory, depending on what you want to do, there's an awful lot more to learn in that.”

Classical physicists the world around seem to regard String Theory as a kind of novelty, as something not too ground breaking or worth concern. Naturally, I had to ask her about where she stood on the bitter rivalries between String Theorists and classical physicists.

“Probably on the fence, to tell the truth. I think it's really stupid to just start criticizing String Theory for the sake of it. To be honest I think some of that is just sour grapes or jealousy of the fact that String Theory has become so dominant. On the other hand I think there is some justice in criticism that String Theorists seem to act as if they have the monopoly on the way the world is and on fundamental physics. I think that's not true either. But I think that to ignore the achievements of String Theory is just unfair. Yes it doesn't go as far as it claims it does, maybe it doesn't do things quite as rigorously as it claims it does, but it's given us an awful lot of insight and it's opened up all sorts of new avenues that we never imagined were there and I think it's a little bit of sour grapes. So it does a lot. I think there's a resentment with the dominance there is, there's some truth in that. Personally, I think it's been a real asset, actually.”



Dr. Ruth Gregory of the University of Durham giving her talk, titled “Circumventing the Eta Problem” at CERN.

Many competing theories to String Theory have emerged in its wake, including, but not limited to Loop Quantum Gravity. Working with the familiar General Relativity and excluding the sometimes bizarre notion of 7 extra spatial dimensions, I asked Dr. Gregory about whether or not Loop Quantum Gravity is as serious of a contender as I’ve heard.

“I guess the guys that work on quantum gravity tend to be very formal and apart from one or two exceptional individuals there, I'm not sure they're really making anywhere near the same level of progress and actually trying to feed into issues in either experimental or observational physics.”

Lots of attention has been centered on ongoing missions to detect gravitational radiation as well. Predicted by Einstein’s General Theory of Relativity, gravitational radiation is supposed to be emitted in the wake of very energetic gravitational fields, like those around two orbiting black holes, for example. To date, none have been observed. However, experiments like the Large Interferometer Space Antenna (LISA) and the Laser Interferometer Gravitational Wave Observatory (LIGO) are and will continue hunting for the elusive radiation that could help to solve many other mysteries in astrophysics.

“Gravitational radiation hasn't been observed yet, but there's a lot of excitement because the experimentalists working on it are reasonably confident that a detection is right around the corner. Around the corner means like, 5 years. It's mainly because they're starting to get to the level where that they feel they have a good handle on their experiment's systematics, on their equipment. And they’re getting to the stage at the same time where numerical work has really come in a long way in the last 5 years. So they're getting to the stage where they're actually beginning to place bounds on things, and I have some colleagues who interact with people who work on these experiments and they're sort of saying that if they were lucky, they would see something, say, next week or next month, but it would be luck. It would be if there was an event close enough. Whereas in 5 years' time, it would be quite a statement if there had not yet been an event observed sufficiently close. And, of course, by the time you get to any of these space observatories, then they won't be able to just say, ‘I’ve seen one', they're actually going to start to do some real observation. It's going to be a new tool for astronomy."

Speaking with Dr. Gregory helped me to realize that all the people at the conference were just as approachable and interesting to talk to as she was, not nearly as intimidating as I had initially felt.

Hawking

The following day was the most exciting of the conference. The air had a certain electricity to it as the sessions ended early in preparation for Dr. Stephen Hawking's talk that he was to give in a few hours time. The last time I had seen him was when he gave a public talk with Brian Greene in Seattle almost 4 years ago. His state of health had not been great and he had to do a live broadcast from California instead of being on stage in Seattle. Eager not to be stuck in literally the last possible row, I grabbed the best seat in the house that a non-VIP could get: just two rows from the great physicist himself.

Hawking is famed for his work on black holes, popularization of science and also his inspiring fight against the motor-neuron disease, ALS, also known as Lou Gherig's disease. It would not be an exaggeration to declare him the most famous physicist of our time. He commands great respect from fans and critics alike. He spoke the day I was presenting my poster. I was explaining it to one of the many researchers representing Portsmouth, when, on my way back to the auditorium to attend the last of the talks for the day, Dr. Hawking was sitting right there with two of his assistants.

I can only describe the feeling as being like a deer in headlights. I was frozen. Here was one of my all-time heroes completely open to me going right up to him. I was worried at the same time, however. Throughout the conference, I felt the CERN campus lacked a certain kind of authoritative security to keep people out of where they shouldn't be. Maybe their security is better spent on guarding the billion-euro LHC, but several times throughout the conference I could have just ambled anywhere on the campus I wished. Maybe there's nothing wrong with that, but when Hawking was sitting outside the lecture hall, nothing could have stopped me from going up and drawing a moustache on him.

I consider those that popularize science in a responsible manner to be worthy of a high level of respect in my books and I've met face to face with many of them. But, by far, Hawking has a sort of aura that freezes you in your tracks. Maybe he didn't need the security after all. I debated in my mind back and forth if I should go up and talk to him, or ask his aids if I could. This was the most nervous I have ever been in my life. I caved. I couldn't go through with it. I walked right by him close enough to graze the end of his wheelchair with my elbow as I continued up the stairs to the main auditorium, listening to his operating system beeping as he selected words to communicate with his assistants.

In retrospect, I wish I could have just gone up to him and said, "thank you," for all the inspiration he's given me and countless others. I'm sure he's aware of it and I'm sure he's heard enough of that at this point in his career. Maybe I was just seeking some cathartic solution to repay the great gift of scientific wonder Hawking and his cohorts throughout the ages have given me, but I felt like I missed an opportunity which I won't ever have again.

This was also evidenced by the fact that the guest lecture he gave had to be broadcasted into 4 other auditoriums simultaneously to deal with capacity overflow issues at the conference. The main auditorium for his live talk began to get packed nearly an hour and a half prior to the talk. With everyone on their laptops at the same time in the same place, the wireless network was almost ground to a halt entirely.

Prof. Stephen Hawking giving a colloquium talk titled, "The Spontaneous Creation of Universes" at CERN.

Now the security guards had arrived, probably in response to the crowd that had gathered outside the auditorium's entrance, desperately wanting to get a fleeting glimpse of the frail physicist in person. As the time drew nearer, the crowd outside finally dispersed to the other halls to watch the broadcast, shooting various scowls of jealously at me and others in my row through the glass out in the hallway. Like a crowd of people before some kind of rock concert, the entire room was filled with wall-to-wall noise of typing, talking and taking pictures. And then, dead silence. It was as if all the air had been sucked out of the room, or just out of people's mouths. Because Hawking can only communicate now via a switch that recognizes his blinking, flash photography had to be turned off to keep his vision from being impaired. The faint sound of shutters clicking sounded like a swarm of bees with the number of people all taking photos at the same time right as he rolled in. Then you could hear a pin drop from a hundred yards away, it was so quiet.

After a minute or two of getting situated with an assistant ready to advance the slides of his presentation, "The Spontaneous Creation of Universes", he asked, "Can you hear me?" to which the crowd roared in cheers and applause.

Unlike his public talks, this one was definitely geared towards the experts in the room. He described how universes could arise seemingly out of nowhere through the use of scalar fields. A scalar field is something that has a certain number, but not a direction associated with that number, at each point in a space. So, for example, temperature variation throughout a room is a kind of scalar field, since you have a temperature (which is just a number) associated with each point in that room. Scalar fields in cosmology would be kind of like gravitational potential energy. You have a certain 'number' of it at each point in space around a massive body, but that number doesn't point in any direction.

Hawking's talk was brief, but it was an acceptable briefness since he did not pre-arrange his talk before hand. The way Hawking communicates is taxing: a cursor flashes between two options and he selects one with a twitch of the eye to select a category, then a set of words then a word itself. Instead of blinking out the presentation beforehand to make a longer one, his 20-minute long talk was done entirely on the fly in the auditorium.

The crowd gathers around Hawking at the end of his talk.

At the end of his speech, he asked if there were any questions. The room was dead silent once more. I wasn't sure if this was because everything he was talking about was patently obvious to so many of the CERN employees and conference attendees, or if it was so far over their heads they couldn't ask any questions. At times in the conference if you didn't make something clear in your talk, the audience jumped on you like a pack of hungry lions. If it was the case that Hawking's talk wasn't all that clear to the audience, they didn't pipe up. Of course, I haven't taken graduate-level general relativity to determine that yet, but I imagine if I had, it would have made more sense.

At the end, he was given a warm applause, followed by a crowd rush that could only have been compared to something like a football team winning a longshot, come-from-behind victory in their home stadium. I was kind of dismayed at how many people from the audience just kind of went up and crowded around him. For what, I'm not totally sure, but it seemed inappropriate. As I described before, when it was just him and his assistants in the hallway, I was too nervous to even thank him. Now dozens of people seemed totally unaffected.

I'm kind of surprised at the lack of security on stage. One may ask, what's the point of security for just a physicist? It's a perfectly reasonable question to ask, since he isn't a rock star, but he's still a world renowned personality. I would say, of many of the public figures that are also revered for being academics, Hawking probably deserves the *most* security of all of them. The crowd rush kind of saddened me insofar as people having a subdued respect for him.

By comparison, at the American Physical Society, before and after Nobel Prize winner Dr. Makoto Kobayashi's talk, a small crowd gathered around him, but kept a respectful distance and remained respectful as far as I could see. In this case with Hawking, I couldn't even see what was going on there were so many people. I can only assume at Hawking's public talk at Geneva University later in the week that he was treated with a bit more respect from the audience.

…The Large

The theory of inflation was a central part of the conference as well. Inflation is a model of extreme universal expansion at a very, very early time in the universe's history just after the Big Bang. Faster than you can blink your eye or you can snap your fingers, the universe inflated from something very tiny to just about the size of the visible universe today. Andrew Liddle, the author of my cosmology textbook and the website from which I found out about the conference in the first place, convened the session on inflationary cosmology. A professor at the University of Sussex, I asked him afterwards about his thoughts on what, of all the models presented that day, were the most "mainstream"

"I think I would say that there's nothing against the simplest models of inflation, the ones Linde first wrote down in 1980s: single scalar field rolls slowly, none of the unusual dynamics going on. That's not to say that I really would believe that is the true model, but there are no indications of how you would imbed that kind of idea into something more complicated like string theory or braneworlds or anything like that. However, it's also fair to say that almost everyone at the conference is working on much more complicated things because the simple scenario that fits the data well has been mined out theoretically, so a lot of people are forced to look at more complicated scenarios in order to make work for themselves."

In the inflation session particularly, but in the conference over all, I noticed that there were many models that balanced on the Higgs field or Higgs particle. One of the cornerstones of the LHC's science missions, the Higgs boson is the final question mark in the standard model of particle physics: a model which could describe everything in the particle physics universe, but couldn't explain why particles have mass in the first place. Mass, it is theorized, is generated by particles like the Higgs boson. When an electron moves through a Higgs field, it 'gathers' mass around it, giving the otherwise massless electron some of the properties we associate with mass, like inertia.

Until relatively recently, particle accelerators have not been powerful enough to hunt for the Higgs. The LHC, located here at CERN would be the first to do so. I asked Dr. Liddle about what would happen if the LHC *didn't* find the Higgs boson. Like all scientists, he began with a caveat:

A plethora of laptops illuminates the CERN main auditorium during one of the talks on dark matter.

"I'm not a particle physicist, so I will not really be able to answer that. Everyone expects it will find the Higgs, but first they have to prove they can get the machine to work at all in the first place before they can have ambitions to find the Higgs. I think it's fair to say that there's no real alternative on the table, which is why everyone expects that they will find it, so it would cause all sorts of theoretical contortions. The nightmare scenario is that they don't find the Higgs and they don't see anything else. And then, really, people really will be struggling, whereas, I suppose, the more optimistic hope is that if they don't find the Higgs it's because they find something else even more strange and interesting. But I'm not a particle physicist, so I would be agnostic on that.

"The one place that people mention the Higgs is that when you work on inflation you're almost always using scalar fields. Whenever cosmologists have a problem," he continued, "they reach for scalar fields, whether it has to be dark energy or inflation. And one of the embarrassing facts is that no one has really found a fundamental scalar field in nature. And the only particle in the standard model of particle physics which has not been verified is the scalar field: the Higgs field. It would be fair to say that the discovery or the confirmation of the Higgs field would reinforce the idea that scalar fields are possible in nature, exist and are routine and hence, are a valid solution to various cosmological problems that come from different energy scales. In the session we just had, there were some people who were talking really about trying to use the Higgs field for other things such as inflation, which is an idea people have been coming back to in recent years. It's looking difficult, but there is some connection there, whereas, for 20 years or so, people have usually thought of the Higgs as not being connected in any way to the other ingredients of cosmology."

In the poster sessions, I noticed a lot of titles centered on the topic of 'non-gaussianity'. It references the Cosmic Microwave Background, the temperature map of the universe. Variations in this map tell us about the growth of structure in the early universe. With current technology, the temperature across the night sky seems entirely uniform, with space at a cool 2.7 Kelvin, just a shade above absolute zero. However, variations in this temperature on microscopic levels can tell us about how the universe's growth gave rise to things like galaxy clusters. But, I asked Dr. Liddle, why is it so important to study the map to see if there are any inhomogeneities?

"One reason why it's important is that people are desperate to find observational signatures of their models. So the danger which I was highlighting in my own talk was that there's a very large number of theoretical ideas for inflation, how inflation might occur, coming from all sorts of directions and the number of observational things you could hope to measure are very, very limited. And so you don't have the observational tools to really fix your ideas and compress the models into more restrictive classes where you can learn something. So cosmologists are trying to pick on all the possible things they can examine and one of the things they hope might be observable is non-gaussianity, which is really a measure of non-linearities in the way that structures were created in the universe in the very early stages of inflation. It's interesting because observations have a tremendous power to measure non-gaussianities and the current limit is already down at the 0.1% level of detection. But nevertheless, observations could go at least two orders of magnitude further than that and probe to very, very high sensitivities. What that means is if you measure non-gaussianity, it could become one of the most precisely known cosmic numbers. More so than other things like the spectral index of density perturbations, with their ambitions to measure it to 10% precision with the very best instruments we'll ever have, but non-gaussiantiy could be measured to, perhaps, 1% precision, if it's large enough to be detected by the upcoming experiments. So it's a real tool for getting precise information about what happened in the early universe. Countering that, I would say the balance of probability is that the non-gaussianity is too small to detect, there's no particularly strong reason to think that it's in the regime of where we're able to probe. It's seen as the best hope, I suppose, for a major discovery that would really constrain the models."

A lot of talk was on the subject of observables as well. There were many researchers talking about the potential future discoveries of the Planck satellite and the upcoming wealth of data from the Large Synoptic Survey Telescope

(LSST), of which I helped to do a bit of theoretical work on over the summer at University College London. Finally, I asked Dr. Liddle about whether or not those missions could give any indication about the discovery of future observables.

As dusk envelopes Geneva, a new day with new science awaits.

“That would be the hope. There are different possible futures for cosmology and some of them are satisfying but depressing at once, I think, and others are more interesting. So satisfying but depressing is the possibility that we've already, essentially, measured all of the things that are available to be measured. So, for example, take the dark energy of the universe that's commonly supposed to be a cosmological constant which is just one number: the density of space. If that's correct, then the density has already been measured to a few percent precision. It may be that future experiments will measure it to a tenth of a percent precision, but that improvement is not very interesting because no one knows how to predict it anyway, so even at 3% precision, it's far better measured than the theorist would ever need. So if we go in that direction, we don't discover anything new, then we can say, 'fantastic, cosmology has been the story of the last hundred years, we've learned all these things about how the universe works and here are the rules, this is what we discovered' and that's the end of it. Then you close the book and say we've learned it all, these are the best models, they're not very satisfying because we've not got a very deep level but nature's told us everything it's going to. So that's one possible future and quite a plausible future, I think. The ways that observations have been going have suggested that. The alternative, which would be much more exciting, would be to have a new frontier open of new kinds of observables. So rather than just measuring the same old things like a couple constants to ever higher precision, you find something new to measure. Non-gausianity would be a classic example. If it was measured by the Planck satellite, we wouldn't measure it with any great accuracy, but it would motivate new experiments that would really probe high precision measurements of non-gausianity. In other spheres of cosmology there's things like dark energy that may turn out not to be a cosmological constant, but have some dynamical evolution. LSST may be able to show that there is evidence of some anti-dynamical evolution and, again, that would be a new frontier which would motivate future experiments and make much more accurate measurements.

“These are the two futures and I don't know which way it will go, it's something that's hard to know. It seems to me that a lot of money was invested in cosmology in recent years in a lot of various cosmology-oriented probes. Planck is one of the last of those, perhaps, but LSST and the Dark Energy Survey are still to come online. If that next generation of experiments don't find new, interesting things to measure in cosmology, it's probably hard to believe that funding agencies are going to think it's worth funding yet another generation that will look to higher precision in the hope to find something new. Because they will think, instead, the money is better spent on studying extrasolar planets, or sending probes to moons of Saturn or things like that. So this may be the prime moment for cosmology, that we're at the peak of achievement and it goes downhill, or it may just be the start. It's hard to know, really."

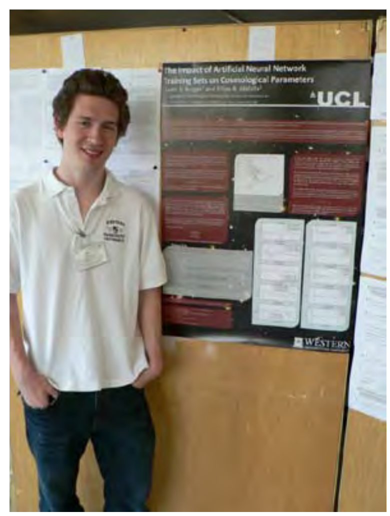
And Beyond

Dr. Liddle held a large part of my understanding of cosmology, since I had been taught from his textbook, which I later got him to autograph. Many things at the COSMO '09 conference opened my eyes to the reality of cosmology and particle physics. It seems as though at just about every academic event I attend this happens. Dr. Gregory had made a case for String Theory and Dr. Liddle had painted a portrait of what could come.

As someone planning on moving into the field of cosmology, Liddle's hypothesis makes me worry a bit. Perhaps this is the golden age of cosmology; the peak where everything goes downhill from here as far as exciting, new research goes. He seems to think that's a viable option. However, with the recent discoveries of dark matter and dark energy, trying to predict what newfangled ideas will spring up in cosmology is hard, if not nearly impossible. Both of those study fields emerged almost entirely out of the blue.

I hope to work one day with the LSST to help Liddle's prediction along in the right direction. This may just be the start of cosmology as we know it. Back in the late 1800s and early 1900s, physicists were in a similar conundrum. It seemed like everything had been discovered and physics was 'done.' We now know that to be obviously wrong, what with the subsequent discovery of an entirely new branch of quantum physics and so much more beyond that and the standard model of particle physics. I feel like discovery will always be around as long as there are people to discover. We humans have a curiosity about our world that has sent us over far away mountain ridges and to other worlds entirely. The fate of the world of cosmology is in the dark for the moment, but it may be the darkness itself that pulls the field out and back into the realm of new discovery. Directly detecting dark matter and the further study of dark energy are two huge question marks that have yet to be explored in full.

In the coming months, with graduate school applications and all, I can only hope to play a bigger part in this world of cosmology: the grandest of adventures.



The author with research poster, "The Impact of Artificial Neural Network Training Sets on Cosmological Parameters."