Thesis Prospectus

Calculating Exotic Hadron Resonances Using Supervised Machine Learning

(Technical Topic)

Science Policy and Its Effects on the COVID-19 Pandemic

(STS Topic)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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I. Introduction

The COVID-19 pandemic has created a new world of uncertainty, where the former power possessed by a nation does not guarantee success. Yet it is an interesting time, as a variety of countries with a wealth of policy differences, economic disparities, and opposing social ideals can be compared on one level – their responses to the virus. Why did some countries succeed while others were left exposed, with lurking issues in their systems suddenly exacerbated to previously unimaginable degrees? The STS Research project aims to understand the source of modern anti-scientific policy and explore its effects on the COVID-19 pandemic, specifically through the lens of Actor Network Theory.

The technical project discusses a different topic. Among the many unsolved problems in physics lies the possible, yet unverified, existence of mysterious particles in the subgroup of the hadron family, a class of subatomic particles that are composed of quarks (Griffiths, 2010). These particles are incredibly difficult to identify given current understandings of them. Thus, the technical project is devoted to studying properties of well-known hadrons, and aims to employ a machine learning algorithm to use those properties to predict the characteristics of hadrons yet to be discovered.

II. Technical Topic

Ordinary hadrons are some of the best understood particles in nature, and are known to either exist as a quark-antiquark pair (meson) or as three valence quarks (baryon) (Griffiths, 2010). Baryons, specifically, are quite well-known even outside the scientific community as they include the proton and neutron. These two particles compose nearly all visible mass in our universe. It is speculated, however, that there are particles consisting of more than three quarks called exotic hadrons. These mysterious particles likely have incredibly short lifetimes and are difficult to predict, as we currently don't understand enough about them to have a dependable method of estimating their masses. However, scientists in nuclear and particle physics have discovered several possible candidates of these exotic states at accelerator facilities in labs across the world, specifically at CERN (translated, "European Council for Nuclear Research") and KEK (translated, "The High Energy Accelerator Research Organization") (Charley, 2014).

The solution to this problem defined in the technical project is to employ the assistance of a machine learning algorithm, specifically a regression supervised learning method, which should allow for predictions of one specific "target variable" using the patterns detected among all input variables. As ordinary hadrons are so well known, the data currently possessed on them can be amassed from the Particle Data Group's Collection on Particle Listings (Particle Data Group, 2020) and then transform it into a readable dataset to "train" the algorithm so that it may teach itself the relationships between variables. After running it, the algorithm will be able to predict possible properties of the exotics based on the number of constituent quarks (4 and above for exotics).

For the purposes of this project, "rest mass", or the energy associated with a non-moving, massive object, was an ideal choice for the variable to predicted by the algorithm. Mass is easily measurable in an experimental setting, and the devices that measure it are increasing in their sensitivity continuously. Continuous improvements in detection technology is imperative to the success of detection of exotic hadrons.

There exist two main goals for the technical project. First, in order to test my findings, I plan to compare output data with data reported on these "mystery particles" that have been detected in labs thus far. The second is to suggest to experimental physicists a possible "energy region" for observation. The end goal for this project is that, in narrowing down the observed region, exotic states will be easier for experimentalists to detect.

III. STS Topic

While the technical project is true science, the underlying problem can still be framed with an ethical, sociological model. Actor Network Theory (ANT), in particular, works for this situation as several of the primary actors are intangible or inanimate. Inanimate actors can play important roles in ANT, as opposed to other frameworks, which is necessary for this project as the main human actors are the researchers involved and the government officials who fund them.

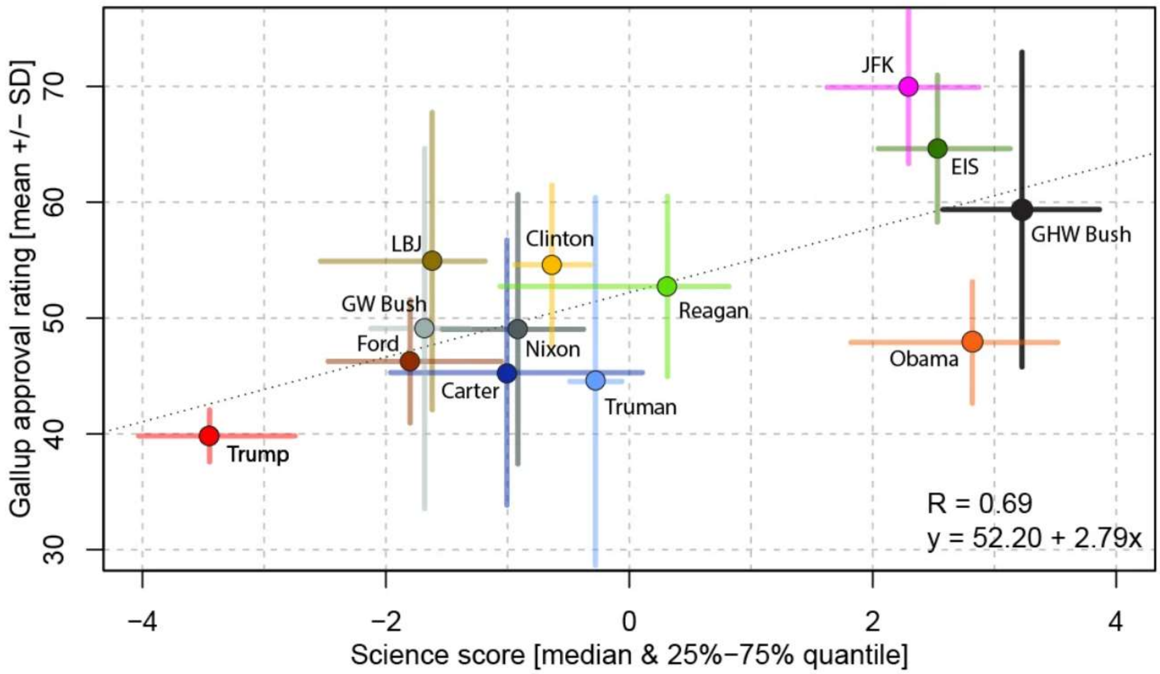
It was this reliance of the sciences on government funding (much more prevalent than private funding) that inspired the STS topic. I was interested in how governments choose to fund scientific research, especially because funding has decreased significantly for the sciences in the past few years. The source of this issue eventually married with the current COVID-19 pandemic, and morphed into studying the distrust of science and the subsequent effects on this period.

Within the STS project, the main actors are scientists, disease models, antiscientific policies, politicians and the virus. At the heart of the research is the network that connects them all. The intention of the STS project is to study this network and determine why countries around the world responded differently when facing COVID-19. This research is important primarily because of the number of lives lost to the virus. According to the Johns Hopkins Coronavirus Research Center, as of November 1st, 2020, the worldwide death toll from the virus had just crossed 1.2 million (Johns Hopkins CRC, 2020). This is especially infuriating because many of those deaths were avoidable and ultimately due to governments ignoring the advice of their scientists. This research aims to identify anti-science as a major predictor of the pandemic's severity through the exploration of several case studies through the lens of the network, and to illuminate the source of this phenomenon.

Anti-science is the movement of distrust and defunding of science, and has grown synonymous with most of modern populism. At its core, modern populism is a political movement which appeals to the common person by contrasting themselves with the "real or perceived elite" (Munro, 2020). It is also caused by a rejection of modernity, which ANT describes as holding science and technology central (Sismondo, 2010), in a time of great change and global integration. This ideology naturally results in anti-science policies because scientists and researchers themselves are often labeled as intellectuals, and subsequently grouped into the "established ruling class."

In principle, a populist government or society is likely going to have little trust or respect for its scientists, a claim which has been verified considering current populist governments like the United States, Brazil and Italy. One letter from Brazilian scientists reports that budget cuts "proposed by the current Bolsonaro government are based on an anti-science ideology", and are making work "untenable for research" as labs shut down (Júnior et al., pg. 1, 2020). It was also reported that United States President Donald Trump attempted to cut $5 billion from the NIH budget in January of 2020 (Mervis 2020), as well as delaying appointments of science advisors, lay-offs at federal science agencies and more. Figure 1, below, illustrates U.S. President Trump's "science advocacy score", as well as his Gallup approval rating, and compares it with those of past presidents from 1945-2016. The graph shown truly emphasizes Trump's tendency towards anti-science ideology (Quigley et al., 2020).

Figure 1.



A final example is the rather grim case of the resignation of a senior Italian Health official in 2019, accusing the government of ignoring scientific evidence concerning the anti-vaccine movement (Day, 2019). All three of the discussed countries experienced a rise in anti-science, populist policies, and all three were, at some point over the course of the pandemic, some of the highest in number of cases (Taskinsoy, 2020).

Conversely, countries that listened to their scientists and adopted containment measures fared well in comparison. New Zealand, known for its successful containment policies, immediately responded to the warnings of scientists and researchers, notably introducing border-control policies to delay its arrival (Baker et al, 2020). China, additionally, also responded quickly once the virus was discovered by taking vigorous, perhaps extreme, measures including forcing those who were ill to isolate (AlTakarli, 2020). Coincidentally, it is a scientific powerhouse, having overtaken the United States in total number of science publications in 2018, and Hu (2020) attributed much of the progress to "generous public funding for science and technology at a time when such funding elsewhere has been under greater scrutiny and less available than before". Finally, in Africa, where millions of deaths were predicted due to poor living conditions, high population density and traffic, mortality and total number of cases remains low because, "…travel restrictions, curfews, and school closures were implemented early in Africa compared with other continents, often before an African country had detected a case" (Mbow et al., 2020). These case studies highlighted will be used to contextualize further research done.

In order to complete this study, countries with varying policy differences and aftermath will be compared further. It is necessary to collect as much data as possible so that a more complete model of the network can be produced. I will continue to draw information from scholarly articles, as well as standard news sources considering that this is still current. I would especially like to quantify my findings by measuring and testing for correlations in number of cases and anti-science policies. I would be interested to compare current data with disease models made in early 2020, as many of those models did not account for anti-science as a variable. I hope that this further research will allow for definitive acceptance of the relationship between anti-science (and, therefore, populism) and a failed COVID-19 response.

IV. Timeline and Expected Outcomes

By early December, the first iteration of the technical project will be complete and, as a "testing phase" of the project, the supervised learning algorithm should be able to predict properties of ordinary hadrons. Before the spring semester begins, I hope to complete the algorithm fully and make predictions for exotics. I aim to present my findings and method in a paper and in a presentation at the Division of Nuclear Physics (DNP) conference in the spring.

The STS project will continue throughout the spring semester, and end in a paper which addresses the COVID-19 pandemic as a complex network. It is my hope that I may also be able to quantify the information discussed before the spring and find a definitive correlation between actors in the network, and that this work is accepted by both scientific and relevant political stakeholders so that I may contribute to the body of literature.

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