The Construction of Crank Science

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Abstract

This article addresses the question how a particular group of physicists - the foundations of quantum mechanics community - constructs crank science. Firstly it shows that the reflection upon cranks within the wider physics community is misleading. Instead, a spectrum of cranks is introduced, which enables a more reflective discussion on crank science. At one end of this spectrum resides the highly skilled professional physicist, who due to controversial work in the area of her very expertise becomes considered as a crank. Secondly, it discusses the construction of these types of cranks by a case study of an ongoing controversy around Joy Christian's disproof of Bell's theorem. Contrary to Reyes Galindo (2011), who identified missing collective tacit knowledge (CTK) as the common feature of cranks, it is argued that a more general ignorance of sociological contingencies constitute that a physicist with a high level of CTK of the community to which the particular knowledge claim is addressed, becomes attributed crank status. This article is concluded by a review of the physicists' concept of cranks, based on the discussed case study: The singularity of the category of cranks is shown to be an strategic achievement of the physics community, which is not only identified as a means to

deny outsiders entrance to a community, but also to expel members from it.

'Big' and 'experimental' are the two adjectives which characterize most of the science and technology studies work covering the practice of physics (for example: Collins (2004), Pickering (1984), Pinch (1986)).[1] In this paper, however, I want to focus on so far underrepresented parts of physics: Instead of 'big science' I am interested in a small community of theoretical physicists and philosophers, concerned about the foundations of quantum mechanics, that has been on the margins of the wider physics community for a long time. The main question I want to address is how this community - in the past often considered as crank science - constructs cranks themselves today.[2]

This article has an at least two-fold agenda: Firstly I show that the reflection upon cranks within the physics community is misleading, which almost entirely focuses on people without or hardly any formal physics education and mathematical skills. I argue that this type of crank represents only one end of a diverse spectrum of cranks; on its other end resides the highly skilled professional physicist, who due to controversial work in the area of her very expertise becomes considered as a crank. Secondly, I discuss the construction of this latter category of cranks by the physics community via a case study of an ongoing controversy around Joy Christian's disproof of Bell's theorem. Contrary to Reyes Galindo (2011), who identified missing collective tacit knowledge (CTK) as the common feature of cranks, I argue that a more general ignorance of sociological contingencies constitute that a scientist with a high level of CTK of the community to which his knowledge claim is addressed, becomes considered a crank. More specifically, for the presented case study, among these ignored contingencies are: ignorance of the contingent forum and violation of mundane social norms, incongruent self-fashioning and pedagogical deficiencies in the presentation of the

knowledge claim. This article is concluded by a review of the physicists' concept of cranks, based on the discussed case study: The singularity of the category of cranks is shown to be an strategic achievement of the physics community, which is not only identified as a means to deny outsiders entrance to a community, but also to expel members from it.[3]

Cranks, Wackos and Crackpots

Branding certain theories as crank theories and more importantly its author as cranks is deeply entrenched in theoretical physicists' training and practice. Theoretical physicists of all kinds every so often receive messages from people who claim to have built a perpetual motion machine or present a rejection of Einstein's theories of relativity. By categorizing such theories as crank, physicists reject them most often sight unseen. As cranks are such a common theme in physicists' daily work, various physicists have reflected upon them and several, humorous and informal "crackpot" indices exist, that claim to allow estimating the crankiness of a certain paper (Baez 1998).

Although questions concerning the boundaries of science have been on the agenda of science and technology studies since its very inception, the phenomenon of cranks has only been studied very recently (Reyes Galindo 2011). Reyes Galindo characterizes cranks as people "who practice physics outside of professionally sanctioned settings". Although they often do not lack technical and mathematical abilities, they "have not been immersed in the physical or linguistic world of professional physics". Building on Collin's (2010) concept of collective tacit knowledge (CTK), Reyes Galindo argues that cranks are individuals who lack the CTK of the field to which they want to contribute. He summarizes various criteria used by scientists to recognized crank theories, most of which are ignorant about the correctness and actual content of a crank theory. "Scientists disregard crank theories," Reyes Galindo argues, "without even noticing what the theory may say. This is not because cranks are wrong, but because in many cases even the questions they pose are illegitimate"(Reyes Galindo 2011).

Reyes Galindo's elucidating characterization of crank science can be seen as a realist approach towards cranks science.[4] Missing CTK can be accounted for the categorization of certain scientific work as crank that can be acquired by immersion to the relevant community. Thus, CTK represents almost a subtle litmus test that allows deciding whether a certain knowledge claim is legitimate or rather should be considered crank. Before extending Reyes Galindo's discussion of crank sciences and proposing a schema of cranks I want to provide two aspects of crank sciences, both of which address the question of how crank papers are recognized. The first example focuses on how young physicists are trained to do so and the second discusses very briefly how technology is employed to identify crank papers.

The physics novices' acquaintanceship with crank science in theoretical physics is achieved by apprenticeship: Anecdotal evidence suggests that senior scientist confront their students with crank papers and ask them to find mistakes in it, which most often is a tedious task. But the students' immersion with crank papers aims not to train them to identify flaws in crank papers faster. Primarily, studying such articles helps the novice to acquire familiarity with crank papers: how they looks like (most physicist write their papers with the typesetting software LaTeX, while the typical crank often uses more common typesetting software), what topics crank papers are typical addressing and the style of the paper.[5] Acquiring this familiarity with crank theories allows students later on in their career to reject such papers sight unseen, without taking into consideration the actual content of the paper.

Not only humans are trained to delineate crank science, also machines were developed to do so. I want to briefly discuss one aspect of how the delineating

of crank science is achieved by the pre-print server arXiv.org, located at and run by the library of Cornell University.[6] In many areas of physics the arXiv has replaced publication in peer review journals[7] and is accessed by physicists worldwide on a daily basis to catch up with the the newest pre-prints.[8] In addition to administrators, who decide according to various criteria[9] whether a paper is eligible for publication, technologies are employed to delineate "good science" from "fringe type science", among them is a language analyzing software. According to the arXiv, the language of outsiders of a certain scientific community is significantly and for their computer software recognizable different from the average member of that community. The arXiv has different categories, related to different areas of physics, to which papers can be submitted, such as quantum physics, astrophysics, condensed matter physics etc. New submissions to a certain category are compared with the average paper of that category and "fringe papers" whose language typically differs are sorted out. Although submissions are not rejected on basis of this technology alone, it provides an important tool for the arXiv to delineate crank science from "proper science". The language difference of outsiders of the community can be understood as missing tacit knowledge. Although people might have mathematical and technical abilities, they have never been immersed to the culture of physics and therefore lack the knowledge of how to write a paper in accordance of the rules of the particular physics community, that physicists acquired due to daily work in that community.[10]

Spectrum of Cranks

I want to introduce a spectrum of cranks that allows for a more systematic discussion of cranks and indicates that the physicists' reflection on cranks focuses only on very specific types, being surprisingly silent about professional physicists, who can become considered cranks. The provided schema, partly based on Galindo's findings (2011), is rather the starting point for a discussion about cranks and does not imply a recipe to identify a crank, as the remaining part of this paper will show. My proposed spectrum ranges between two poles: The 'genuine crank' on the one side and a professional physicist with a high level of CTK on the other.

At one end of the spectrum are what I call the genuine cranks. Their typical work is the infamous perpetual motion machine. A theoretical physicist describes:

> " These people who are not really scientists evidently; they don't seem to be like scientists. They tend to think they solve every important question of physics if not life and science. "

Most significantly, these types of cranks lack mathematical abilities, knowledge of any literature in the field and not only CTK, but have hardly any technical knowledge at all.

Next to the genuine cranks there are the "retired engineers" (Reyes Galindo 2011): persons who have some technical knowledge, but usually in an area very distant from the area of his knowledge claim. This type of cranks are for example engineers with contributory expertise in some engineering field, but they try to contribute with their knowledge claim for example to cosmology. Although, they might be familiar with old literature and refer for example in the context

of quantum mechanics to Einstein, Schrôdinger and Bohr (Reyes Galindo 2011); they are unfamiliar with the current literature and developments in the field. Such cranks have most often rather mediocre mathematical skills, contrary to the mathematical expertise of the professional physicist working in the area that the cranks' paper is addressing. In addition, the language of his paper differs significantly from the average paper in the field relevant to their work and is detectable by arXiv's language software. As these types of cranks have never been immersed to the culture of professional physics, they lack CTK.

Discussions about these two types of cranks are often found in reflection of physicists upon cranks. I want to argue, however there are two additional types of cranks, to which the physicists' reflection often remains silent. These types of cranks, who are professional physicists, are often not openly referred to as cranks. A first hint that there are more than the two presented categories of cranks gives this reflection by the theoretical physicist Joy Christian, who will play an important part in the remainder of this paper:

> " In the physics community you lose your status so quickly. All that happens is they start talking, they don't say much, they just say very little: 'Oh, he used to be quite productive and smart, wasn't he?' That's all they say and it is understood that he is no longer . . . that he is becoming a crackpot.[11] It's not said but understood. "

"It's not said, but understood" entails that there is a reluctance to speak explicitly about the cranks among professional physicists, but nonetheless physicists seem to be very familiar with the process that a member of their community becomes considered crank. This familiarity can be partially accounted for with the physicist acquaintance with crank science (of the above mentioned categories) in their a daily practice and training. In the remainder of the paper we

want to discuss in detail how such cranks are constructed, but prior complete the proposed crank spectrum with two other categories of cranks, both of which are professional physicists.[12]

The third category in the proposed crank schema is a group of people, who are ascribed crank status, despite their long practice as professional physicists. Often they have been very successful physicist in one area of physics and then try to contribute to another (Reyes Galindo 2011). Due to their experience in writing papers, the writing style differs insignificantly from members of the scientific communities they do not belong. Although they are usually highly skilled in mathematics and familiar with the current literature, they nonetheless lack CTK. As Reyes Galindo (2011) shows they do not know, for instance, whether one of the recent papers that they are referencing to is genuinely important, whether their way of addressing a problem is similar to that of the relevant community. Despite their previous achievements, these physicists can become considered cranks by publishing a paper, which indicates that they do not share all aspects of the CTK of the particular scientific community.

The last category will be the focus of the remaining paper: I argue that there is a category of professional physicist, who become considered cranks, although they are highly mathematical skilled and are familiar, not only with the current literature, but also which part of this literature is important. Further, due to their long-standing membership in the particular community they know how a specific scientific problem has to be address according to their community. In short: they do not lack CTK. Nonetheless, by publishing work, which most often becomes controversial, they can acquire crank status.

CTK might be sufficient to discuss the first three of the categories. For the last category of cranks, however, the professional physicists working in the area where they acquired CTK, the situations becomes more subtle. I argue that acquiring crank status is better discussed in terms of violation of mundane social norms, incongruent self-fashioning and pedagogical deficiencies in their presentation of their work, than CTK. Furthermore I want to illuminate some of these factors that contribute that the professional physicist becomes considered a crank by a case study of a controversy in the foundations of quantum mechanics community and argue that CTK ultimately fails as test for crank science.

This spectrum of cranks does not represent a realist approach towards cranks, which a discussion of cranks in terms of missing CTK seems to propose[13] as such realist approach, determining whether the proponent of a certain knowledge claim lacks CTK would amount to estimating the merit of the knowledge claim. To the contrary, the here proposed schema represents a mere overview of the strategic concept of cranks that the physics community uses. While physicists often associate cranks with the first two categories which are often presented as a uniform category, I want to argue that the physicists' conception is much broader and diverse. This schema helps to show this diversity. Further it indicates that the different types of cranks do not have much in common and allows arguing that the singular object of the crank is a rather a strategic achievement of the physics community.

As questions of demarcation and boundaries of science have such a prominent roles in science and technology studies, I want to briefly address how various theories and concepts, that have been discussed by science and technology studies

scholars in context of the demarcation issue - separating science from non-science - fit into the presented crank schema. Well known examples are: parapsychology (Collins and Pinch 1979), homeopathy (Picart 1994) and work that connects what is considered religion and science (Turner 1978). All of these examples, partly based on institutional reasons, have proven to be relatively stable over time in being considered outside the legitimate realm of science. Physicists immediately reject work that covers areas as the mentioned above. I categorize such work, that has been considered non-science for a long time, as genuine crank.[14] Hence the proposed crank schema has different temporal stability: genuine cranks and their work has been usually considered crank for quite some time. Whereas work of the professional physicists who have become considered cranks, can change rapidly from crank to cutting-edge science; so the latter two types of cranks entail much temporal flexibility.

The field of foundations of quantum mechanics in itself provides an illustrative example for such temporal flexibility in what is considered crank: originally the topic about the foundations and interpretation of quantum mechanics was important for the founders of the theory in the 1920 and 1930s. However, after the second world war, investigations in the foundations of quantum mechanics became unfashionable and physicists seriously threatened their careers when engaged in it. Quantum foundations then was considered philosophy, only to return back to the realm of physics and information science at the latest in the 1990s with the emergence of quantum information.[15] In short: Foundations illustrates cunningly a shift from a legitimate area of research to crank science and back with in a few decades.

In addition to the temporal flexibility, there is another flexible aspect of the proposed schema, related to the two types of cranks, who are professional physicists. As their area of expertise is important, whether they are categorized one way or another, the proposed schema has to be seen relative to a particular scientific community, which we will discuss in more detail later.

Table 1: Spectrum of Cranks

	Genuine Crank	Retired Engineer	Professional Physicists	
Typical work	Perpetual Motion machine	Einstein's theories of relativity	outside primary area of expertise	inside primary area of expertise
Mathematical abilities	low	medium	high	
Collective tacit knowledge	no			yes
Language difference	detectable		non detectable	
Familiar with literature	no familiarity	outdated literature	current	current and relevant

Another aspect that seems worth mentioning in this context is the relative number in each of the presented categories: the number of genuine cranks is far bigger than professional physicist, who are ascribed crank status due to work related to the field in which they are trained and acquired CTK. Despite their small number, studying this category provides new insides in the physicists' concept of cranks, its scope and function.

As we will show that missing CTK fails as an identification sign for the last category of the spectrum the following questions remain: How can a professional physicist be become considered a crank? How is the last category of cranks constructed? Why does a scientific community ascribe to some of its members crank status, but not to others who engage in very similar work? I intend to

provide some answers to these questions by discussing an ongoing controversy over a knowledge claim by Joy Christian, long standing member of the quantum foundations (in what follows for brevity often referred to as foundations) community, who claims to have disproved Bell's theorem, but before review some features of the foundation community.

The quantum foundations community is very inhomogeneous group of researchers all of whom are interested in questions of the interpretation of quantum mechanics, the (im)possibility of hidden-variable models, problems around measurements in quantum mechanics and very prominent entanglement and non-locality due to Bell's theorem (Schlosshauer 2011). Many of its members have established a career in different areas of physics and then switched to quantum foundations. Some are philosophers, but hold a PhD in physics or vice versa or have degrees in both fields, some work at physics departments others at philosophy departments. In addition there exists a fairly big diversity in their approaches towards foundational issues in quantum mechanics, often but not exclusively along the lines of a particular interpretation of quantum mechanics such as: Copenhagenists, Bohmians, Everettians, Bayesians to name only a few.

Although people with different approaches to quantum foundations often vehemently disagree of each other, there are nonetheless some important results in the field, which are universally accepted, not only in terms of correctness, but also importance. One such cornerstone in foundations is Bell's theorem. By some in the community referred to as the "most profound discovery of science" (Bertlmann and Zeilinger 2002, Stapp 1975) it can be understood as a means to unify an otherwise very heterogeneous community. As part of the

controversy around Christian entails disagreement about the actual statement of Bell's theorem, we will postpone a detailed discussion on Bell's theorem to the later section in this paper.

Constructing Institutes, Constructing Cranks

The main proponent of the case study we want to discuss in detail is Joy Christian, who starts his training in foundations of quantum mechanics at Boston University. He obtains his PhD in 1991 under Abner Shimony, one of the foremost authorities in the foundations community, philosopher and physicist, and best known for the Clauser-Horne-Shimony-Holt (CHSH) inequality. Subsequently Christian becomes a junior researcher fellow at Wolfson College of the University of Oxford in foundations of physics, where he closely works with mathematical physicist Sir Roger Penrose during the 1990s and publishes a high regarded paper on quantum gravity (1997).[16]

During the early 2000s, after completing his postdoctoral appointments at Oxford University, he remains a member of Wolfson College at the university and continues with his research, which culminates in a number of publications on various topics in foundations of physics (Christian 2004; 2005a;b). In 2005 he joins the quantum foundations group at [name of the research institute] as a long-term visitor.

This [name of the research institute] is started around 2000 as a philanthropic enterprise; set up to become a world leading physics institute. Among the aims of the [name of the research institute] is to organize research in theoretical physics in a different way. The initial idea for the structure of the institute is a "flat hierarchy of a true community of scholars", including no faculty members, but only senior scientists, with renewable contracts and post-docs with non-renewable contracts. In addition, various long- and short-term-visitors complete the research staff at [name of the research institute].

The funding executive director of [name of the research institute] Charles Nitro wants to create a space in which in addition to traditional research directions such as string theory other less popular fields as for example quantum gravity and quantum foundations can be pursued. Motivated by his own experiences as PhD student in theoretical physics in which "the Olympic heights of pure reason, when examined in more detail, turned out to be reducible to a furiously contested form of highly esoteric tribal warfare"Nitro (2009)[17] wants to construct an intellectually open place, where physicists are invited to challenge existing concepts of theoretical physics. Physicists from different backgrounds and research interests are encouraged to question each others assumptions. No research program is dictated, but researchers can pursue the research they are most interested in. A researcher describes the atmosphere that is constructed at the institute:

> " Everyone was brought in very fresh and told to have great ideas and it was trying to do something different, it was trying to say: 'Lets remove the bureaucracy, let's remove various other things, let's give these bright young things the freedom and space to just think about deep stuff and trank [tranquilize] them up with new ideas and [let them] establish their own research program.' It was all very heady and intoxicating and it did create the feeling for most of the people there to do something different. "

Christian arrives at the institute in 2005, initially fully integrated and valued among his colleagues for his "encyclopedic knowledge" of physics, when engaged in various discussion at the institute. In 2006 he co-organizes a conference in honor of one of the foundations community's most influential figures, his former supervisor Abner Shimony.

In March 2007 Christian uploads a paper on the pre-print server arXiv.org, entitled: "Disproof of Bell's theorem with Clifford algebra valued hidden variables" (2007). He presents a local-hidden-variable model that - according to his argument - is capable of reproducing the quantum mechanics predictions. As stated in Bell's theorem that should be impossible. His argument is based on algebraic objects, bivectors that he uses to form his model. By providing a counter-example to Bell's statement, Christian argues, that his model provides a disproof of Bell's theorem.

Although [name of the research institute] is constructed as a place in which "basic assumptions could be probed and tested, questioned anew" (Nitro 2009), the sentiment towards Christian changes almost immediately. Confronted with Christian's challenge to the basic assumption of quantum foundations, scientists react very differently from how the institute is constructed and how the construct themselves. Contrary to the proclaimed openness of the foundations community and their revolutionary self-fashioning,[18] people often are not willing to engage in a discussion with Christian at all. One of my interviewees describes:

> " There was definitely an element of, he was frozen out, people just weren't interested in talking to him anymore [...] and one person, after a couple of drinks expressed the opinion that he should have just been stuffed into a car, driven to the airport and put on a plane back to the UK for having put out this paper. "

Some of the researchers start to associate Christian and his work with cranks. I suggest that their reaction is best understood in terms of degradation rituals, a concept widely discussed in anthropology, religious studies and sociology but only recently introduced in the science and technology studies context by

Therese and Martin (2010). Their work is partly based on Harold Garfinkel's concept of degradation ceremonies ("any communication work that lowers a person's status in the group context") (1956) and on Catherine Bell's work on rituals (2009). Therese and Martin identify degradation rituals as a means to attack "the currency of the operation of science: a scientist's reputation" and define them as "particular practices - forms of ritualization- that work to transform the status and identity of the ritual target in a devalued category within a group or to expel the target from the group entirely"(2010). Furthermore they suggest discussing degradation rituals in terms of private and public, embodied and textual, formal and informal acts.

Ascribing crank status to a physicist can be discussed in terms of such degradation rituals, because associating a professional physicist with cranks - which are persons, so the picture that physicists present, residing always outside the realm of legitimate, professional physics - devalues a physicist and can eventually expel him form the physics community entirely. More specifically, I suggest in the case of Joy Christian that shunning him from social activities and engaging in derogatory gossip are best understood as private degradation rituals. In addition, semi-private, embodied degradation rituals are employed when Christian presents his work at [name of the research institute] in form of a seminar talk. Shortly after he starts, a senior scientist interrupts and heavily criticizes Christian's work, therefore alluding to that fact that it is not even worth spending time to listen to Christian's talk. Many people leave the lecture hall, immediately. Furthermore, at the end of the talk the common appreciation of the speaker by applause is withheld. Denying what is otherwise taken for granted further exemplifies that the actions of some researchers at [name of the research

institute] are best understood as form of ritual, following Bell's comprehensive concept of ritualization (2009). All of these various degradation rituals originated and further solidified that Christian has become ascribed crank status by some of the researchers at [name of the research institute].

Soon after he publishes his papers Christian leaves the [name of the research institute] and returns to Oxford, where he remains affiliated with Wolfson College. Although his position at Wolfson does not provide any income he continues with his work on Bell's theorem, publishing a series of papers on the e-print server arXiv.org and attracts some funding by the Foundational Questions Institute (FQXi).[19]

In the following I want to show that sociological contingencies or the ignorance thereof constitute that Christian has been ascribed crank status by the foundations of quantum mechanics community; which already happened early on in this controversy. Before embarking on this detailed analysis, I want to provide - for the sake of completeness and as the controversy around Christian's claim has continued - a brief history of the controversy from the time after Christian returned to Oxford till today.

The mainstream foundations community initially mainly ignores Christian's work, only a few PhD students criticize his papers on the arXiv (Holman 2007, Pawlowski 2007a;b).[20] The most well-known critique is Philippe Grangier, a research director of the French National Centre for Scientific Research (CNRS) and professor at the Ecole Polytechnique (2007). Christian replies to all his critiques (2007) and continues to publishes[21] his papers on the arXiv,[22] but in 2011 he drastically change his communication strategy. When the topic on various internet fora and blogs appears between 2007 and 2011 Christian

would sometime participate in the discussions, only to briefly answer questions, without ever initiating a discussion by himself.

This would change after FQXi awards him a small grant over $12 000 in 2010 which would allow him to publish a book about his research on Bell's theorem[23]. Christian is obliged to start a blog entry at the FQXi website about his book. The first entry in Spring 2011, receives about average amount of attention on the website, but after a second blog entry a long lasting exchanges starts. By August of 2012 the blog attracts more than 8 000 replies. Many of them from physicists or mathematicians with no academic affiliations and people with no formal physics education, a few of them support Christian's position on Bell's theorem.

In February 2012 Richard Gill a mathematician at the University of Leiden joins the controversy around Joy Christian's work, by publishing a paper on the arXiv where he claims to have identified a mathematical error in Christian's calculation (2012). The claimed error, however, turns out to be the same as raised a few months earlier by another critic (Moldoveanu 2011a;b). Gill explains in his paper that "the mathematics has to stand on its on" arguing that Christian's paper has to be error free regardless of the physics interpretation of his mathematics. Christian's arguments against Gill appears a few days later on the arXiv (2012a).

Despite Gill's claim, his math does not stand on its own, but his rejection of Christian's knowledge claim was accompanied by intense work in the contingent forum. Gill's paper ends with "Sanity has been restored"[24] thus associating disproving Bell's theorem with unhealthy mental conditions. Within a few days of appearance of his papers Gill advertises the alleged flaw in Christian's papers

not only on the FQXi website, but via Twitter, his own website, Wikipedia, on various other physics blogs and forums (2012a, 2012b, 2012, 2012).

In May 2012 Scott Aaronson computer scientist at MIT offers a wager on his well-known blog: He offers to pay $100000 to anybody who can demonstrate that scalable quantum computing is impossible. Christian, who had met Aaronson at [name of the research institute], where both had visiting appointments at the same time in 2007, challenges Aaronson's offer, argues that he already demonstrated the impossibility of scalable quantum computing which, according to Christian, is based on the validity of Bell's theorem in 2007. He furthermore offers a counter wager and offers to pay $200000 to the person who would build the first scalable quantum computer.

The discussion on Aaronson's blog (Aaronson 2012) quickly starts to evolve into a very emotional and name calling exchange. Culminating in Aaronson's request to FQXi - both Aaronson and Christian are members - to stop funding Christian's work. He furthermore threatens to withdraw his membership from FQXi and urges other members to do so as well. In addition he calls upon Wolfson College requesting that they sever their connections with Joy Christian, whom he considers to be a charlatan. Several members of the foundations community support Aaronson in his claim that Christian's work is without validity. In addition to requests on Aaronson's blog, the head of Wolfson College is contacted directly and urged to sever Christian's affiliation.

In 2012 James Owen Weatherall, philosopher and physicist at the University of California in Irvine publishes his critique on Christian's model on the arXiv (2012). Christian's reply (2013) was, however, not seen as appropriate for the category quantum physics by the moderators of the arXiv, in which Christian

has published all his papers so far but only allowed to be published in the category general physics, at category, that is hardly read by professional physicist and a category that the arXiv regards as a place were crank science can be disposed to.

In January 2013 the funding agency FQXi announces that it has "convened a special panel composed of experts exquisitely qualified to read, understand, and evaluate both Christian's work, and the way discussion of the work has played out in the public sphere" (Foster 2013) which unanimously concludes that "Christian's work on Bell's theorem is flawed" and recommend against further funding any of Christian's research on Bell's theorem. However, no details of this report was made public. Several commentators on the FQXi website pointed out that FQXi's discussion to convene an expert panel to evaluate Christian's work and its conclusion contradicts FQXi's mission statement.[25]

Although this more recent period of the Christian controversy covers a lot of interesting sociological issues, such as the role of blogs and other web 2.0 based forms of communications in scientific controversies, we want to focus only on the early phase of the Christian controversy and discuss several sociological factors that constituted that Christian becomes considered crank and expelled from the foundations of quantum mechanics community. However, I am not providing an exhaustive description how Christian became considered as a crank, but rather discuss a few crucial issues, most of which are related to the ignorance of social contingencies.

Negligence of the Contingent Forum

Christian initially paper creates bewilderment among his colleagues at [name of the research institute], as he did not share his ideas on Bell's theorem with his colleagues prior to uploading his paper to the arXiv. Frank[26] explains:

> " I mean he was at [name of the research institute]- that's the other thing - like he's got the largest concentration of people who know this stuff like the back of their hand sitting around him and he didn't talk to any of us about it- Why? - before he put it out there. That's perplexing in a way, it was a wasted opportunity. "

Christian explains that he never engages in discusses papers before he puts them on the arXiv. Although collaboration in theoretical physics has become more common than a few decades ago, Christian's practice is not unusual. Contrary to other areas of physics, which are more focused on experiments and often practiced in a large collaborations which necessitates discussions about papers before they are published, some researcher in theoretical physics prefer to publish their papers mostly on the arXiv, before sharing their findings with their colleagues. However, most of such papers do not have as far reaching claims as Christian's work on Bell's theorem.

Collins and Pinch (1979) distinguish between two different fora in science: constitutive and contingent. The constitutive forum forms, what can be considered the "outcomes" of scientific activity: published papers in scientific journals and formal conference talks, which are presented in terms of very specific types of arguments: experimental and theoretical evidence and common in theoretical physics: theorems and mathematical derivations. The contingent forum represents the more informal side of science. The language in this forum is more

direct; research is evaluated in terms of arguments, which never appear in scientific articles: such as the reputation of the university where the researcher is located, her pedigree and previous achievements. It is this forum where a crucial part of the scientific practice is localized, which, however, is hidden when only looking at the published results of science. Scientific practice in the contingent forum takes place during lunch and coffee breaks, small seminars, discussions via email and more recently on blogs.

Christian divulges his work only via the constitutive channel and neglects entirely informal discussions in the contingent mode of science. His colleagues clearly expected him to share his findings privately before putting it on the arXiv, given the importance and wide ranging consequences of his claims. By avoiding to discuss his work in the contingent forum before publication I suggest that Christian violates a mundane social norms, stating that one should inform one's peers about novelties in private, before making them public. For a knowledge claim such as Christian's that questions the foundations of quantum foundations, a member of the foundations community is obliged to informally discuss it with his colleagues before publishing it.

The role of norms in science has first been discussed by Merton in terms of universalism, communism, disinterestedness and organized skepticism (1973) and earned heavy criticism by early science and technology studies scholars. Barnes and Dolby (1970) stress in their critique on Merton's norms that they not only lack content and are stated too loosely, but norms in science, unlike in Merton's presentation, have been changing over time. As there is no set of overall norms reflecting the vast and radical changes from the "string and sealing wax" science of the 17th century to the highly specialized and increasingly esoteric

scientific practice as of today. In addition they analyze some of the norms and conclude that they are not specific too science, but they merely reflect loosely stated norms with general validity in societies (Barnes and Dolby 1970).

Another influential critic of Merton, Mulkay (1976) argues that the Merton's norms are not institutionalized in the rewards system of science, hence they can not govern scientist behavior. Nonetheless Merton's finding of these norms is of significance, but Mulkay identifies them mainly as rhetorical tools of scientists, used in the interaction with lay audience. In this context scientists employ norms to support their case that science should be regard valuable for its own sake and science should be best governed by those who understand these norms at best: scientists. Mulkay suggests that scientists by using this self-presentation which secures scientists' special status in society, utilize an "occupational ideology" (1976).

In stressing that Christian violated mundane social norms we fully agree on Barnes and Dolby's critique of Merton that there are no universal norms that are governing and specific to science, but we rather show that certain, more general norms, regulating social interaction in society, play - and this is hardly surprising - a crucial role in the social activity science. My emphasis on the importance of such a mundane norm can further be understood as strengthening Mulkay's argument of science as an ideology: for the official self-presentation Merton's norms are used (what Barnes and Dolby call professed norms), but the internal behavior is regulated by more mundane norms (statistical norms), which are the same as in any other group of the society.[27]

Although theoretical physicists often tend to picture their trade as one in which they work in isolation, knowledge claims in order to be successful re-

quire informal discussions in the contingent forum. If the contingent forum is neglected, hence the mundane social norm is violated, physicists can acquire crank status within the particular scientific community. Frank further explains:

> " Well, yeah I learned a lot of seeing what happened as result of that [laugh] in fact, I certainly think if I would came with an extraordinary result like that or felt that I had something rather novel, I would make sure that I talked about it privately to a fair few people and convinced them that I actually got it right first. At least being convinced that their reason for thinking I hadn't got it right were... at least found out what the reasons would be. I certainly would wanna do that now myself seeing what happened. "

Frank's statement underlines that Christian's behavior can be seen as a violation of social norms. The importance of these norms, however, was not even clear for Frank. He indicates, that to avoid similar explosive consequences as in the case of Joy Christian, one ought to consult the contingent forum, before presenting one's knowledge claim publicly.

The Unreasonable Effectiveness of Flamboyance

Far from arguing that Christian simply violated a mundane social norm, I want to focus on the problem of under-determination that accompanies rules and their application, a topic that has been extensively discussed in the science studies literature, most of which originates in Wittgenstein's rule-paradox. Bloor (1983), Collins (1992) and Barnes (1995) all stress the importance of the social basis of the application of rules. Barnes (1995) focuses on rule following in the context of social norms and Collins introduces the enculturation model to resolve the problem of rules and their application and provides various case studies in which knowledge is being treated like "or at least based upon, a set of social skills"(1992).

Further motivated by the above discussed critiques of Merton, who both conclude their critique stating that norms can not be independently assessed without "specific bodies of scientific practice and technique"(Mulkay 1976), I want to take into account context of the scientific community, which originally ascribed crank status to Joy Christian. I have already briefly discussed the foundations community and their stance in the wider physics community, but now focus more on the foundations group at [name of the research institute] and show that the above stated mundane social norm does not have binding character for every member of the foundations group at [name of the research institute].

Charles, the director of the [name of the research institute], compares Joy Christian with John, who had a very different approach in quantum foundations. Both, Christian and John were initially valued for their "encyclopedic knowledge" of physics. To begin Charles emphasizes, that similar to Christian's

knowledge claim, no one at the institute believed that John was correct in his approach to foundations of quantum mechanics:

> " Other than one or two of his post docs nobody thought that John was right, nobody believed in John's approach [...] other than John. Nobody I knew. But virtually everyone with the exception of a couple of people thought that John was great for the institute. [...] And I say this because there was a sense that this guy was wrong, but OK, he defends his points well, he's got his own points, he's very original, he's has his own ideas, he's a smart guy, he knows a lot of stuff, he makes a real contribution to the place. So from my biased, detached, ignorant, bla bla bla perspective I don't think there was any real difference in Joy believing in his own thing, for his own reasons and being respected for his intellectual capabilities and his right in whatever he wanna to believe in and say John in a similar way. "

Charles emphasizes that both Joy Christian and John are considered wrong. Nonetheless there is a fundamental difference related to their self-fashioning within the foundations group at [name of the research institute] and the foundations community in general:

> " You might think that personality has nothing to do with it. But I think it does have something to do with it. John is a flamboyant guy, he's a confident guy and John has been outside of the mainstream for so long, that's part of his character. More than that, it is very clear that, clear is maybe too strong, but one can't help but suspect that he actually quite enjoys being outside of the mainstream and that's part of his persona and people know that, of course you can help notice that.
>
> Joy is quite different, Joy is not flamboyant, like John is, Joy is somebody who's been to a large extend in the mainstream, in the mainstream

of foundations whatever the hell that means,[28] but anyway you gonna understand my point. So for John you'd perhaps be not only willing to countenance something that runs against that you might have imagined but you are almost expecting him to do something which is against what you might have imagined. Whereas for Joy it's quite different, [...] for Joy it's quite a shock, a surprise that he'd had have done this. So there ends speculation number 5571. It was almost like a stealth bomb, that someone like Joy, you wouldn't expect he'd be doing something like that. While with John, well that's just John. I mean it's John being John and you'd expect him to do something outlandish. I mean you'd expect John to just do different stuff. And I think you might say that should haven't anything to do with the scientific process, it probably shouldn't, but it does, because they are people that are engaged. "

Charles description of John's status in the community has some some parallels with the character of a court jester, as he is expected to do "something outlandish" and enjoyfully positions himself, for people noticeable outside the mainstream . As Otto (2001) shows in her work on jesters, covering the phenomenon from all over the world, one of the common features almost universally shared by all jesters over the periods and different locations, is that they are allowed to speak freely without having to fear any consequences:

" [...] they got away with speaking truth to power by not threatening power. Rarely were jesters likely (or much inclined) to try stealing power for their own benefit [...] they weren't revolutionary in the sense of trying to destroy the existing power structure, preferring to change behavior as the outsider operating within the system (of Chicago Press 2001). "

John is not seen as a threat to the community, as his court jester-like position entails that he is expected to show behavior that is deviant from the mainstream

of the quantum foundations community. He is allowed to be ignorant of the contingent forum and the above stated mundane social norm, when presenting a knowledge claim. Whereas Christian, as an insider of the community, with an entirely different habitus, cannot simply publish a paper without informing his peers beforehand. He, obliged to follow the social rules of the 'court' is expected to carefully discuss his findings before going public. Although his knowledge claim might be quite similar to one of John's, as Charles suggests, it comes as a surprise and "like a stealth bomb" challenges the community, by questioning one of the most fundamental theorems of quantum foundations.

Similar to ancient or medieval courts where jesters did not have to fear any consequences when speaking freely, but were expected to do so and were often rewarded, John is socially rewarded for his deviant behavior (he is "great for the institute"). Christian, who has no jester-like position in the community, by speaking freely, openly criticizing and rejecting the foundations' Holy Grail, thus threatening the community, experiences similar consequence as deviant behavior at ancient of medieval courts: he is expelled from the community.

If we follow Charles' assessment that "personality has something to do with it" and further take into account that the researcher's personality is always embedded in a particular scientific community, then a much more subtle picture on the relevance of violation of mundane social norms emerges. Nonetheless this picture does not weaken my argument on the importance of the contingent forum when presenting a knowledge claim. As John's self-fashioning within the community as an outsider in congruence with his "different" research program can be seen as work in the contingent forum, wheres Christian's way of present-

ing his claim is incongruent with his position as a member of the "mainstream" of quantum foundations.

Mathematics

In addition to Christian negligence of the contingent forum and his incongruent self-fashioning, pedagogical obstacles contributed that he was attributed crank status by the foundations community. According to a wide held believe, results of theoretical physics - contrary to experimental physics, where reproducing some of the experiments necessitates in addition to experimental skill, often huge financial resources - are thought to be easily accessible, as no tools besides pencil and paper are necessary: "physicists where assumed to write papers whose content other theorist could understand, at least in principle anywhere in the world" (Kaiser 2005). Opposite to this traditional picture, Kaiser (2005) argues, learning and applying the handicraft of certain theoretical paper tools and mathematical formalisms, plays a similar important role in theoretical physics, as acquiring certain techniques in experimental physics.

Among the main obstacles for members of the foundations community to read and understand Christians paper, resides their unfamiliarity with the mathematical tools that he uses. His hidden variable model is based on geometrical algebra, developed by mathematicians William Clifford and Hermann Grassmann in the 19th century and further extended to many areas of physics by contemporary mathematician David Hestenes, which is almost unknown in foundations of quantum mechanics community.[29] Although geometrical algebra is in principle accessible for Christians colleagues through his article and reference therein, hardly anyone in the foundations community can penetrate the mathematics.

Kaiser's (2005) analysis of the dispersion of Feynman diagrams suggest that to spread a new mathematical formalism requires large pedagogical efforts, often personal interaction. Such pedagogical efforts were entirely absent in the initial

period when Christian presented his knowledge claim in a short four pages paper. Although his later papers show a great deal of details about geometrical algebra and some members of the physics community interact personally with Christian to learn and apply this mathematical tool later on,[30] at that period Christian has already become branded as a crank by the foundations community.

Such pedagogical deficiencies of his early article have to be seen in the context of the foundations community. One of my interviewee comments the big variety of mathematical abilities in the quantum foundations community and the heterogeneity of the foundations group at [name of the research institute]:

> " The foundations community is an odd community [...at [name of the research institute]] you had Harry this old wise man who knows an enormous amount of things with a great deal of sophistication. As I mentioned you had John, in my mind an extremely impressive breath of physics and you had other people who really didn't know very much at all, almost at an undergraduate level. They knew their own corner, right, but they didnt have the breath and the depth and mathematical sophistication. "

Members of the foundations community when describing the characteristics of their community often state that the "rules of the game" in foundations are not clear, frequently referring explicitly to Kuhn's Structure, to position foundations as revolutionary field contrary to normal science ("physics properly" and "straight physics"). But this can also be understood that, and this suggest the above quote, the canonical knowledge of the foundations community is not as rigidly defined as in other physics communities. Thus pedagogical deficiencies in Christian's early presentation of his knowledge claim weighted more heavily in the context of foundations as in other physics communities.

Cranks and Evidential Context

Despite my critical position concerning the importance of CTK in the discussion of the construction of professional physics as cranks, CTK is important when the evidential context of a disputed knowledge claim varies. Pinch (1985, 1986) proposes the schema of evidential context of observational reports in the domain of experimental physics. Observation in science, Pinch argues, is situated in a setting, its evidential context, such as previous observations, theories, laws and hypothesis, all of which define its evidential significance. This significance of observational reports "may take on significance in a variety of different evidential contexts" (1985).

I want to extend Pinch's schema to the realm of theoretical physics and provide a short discussion of the evidential context of the theoretical concept of Bell's theorem. This theoretical object was initially and still is contextualized in the realms of quantum foundations. Bell's original paper (1964), entitled "On the Einstein-Podolsky-Rosen Paradox" was situated in a context of the quest of local-hidden-variables, which was assumed to complement the incomplete theory of quantum mechanics.[31] The formulation of Bell's theorem in this context has been summarized by philosopher and physicist Abner Shimony, for his article on Bell's theorem in the Stanford Encyclopedia for Philosophy: "no physical theory which is realistic and also local in a specified sense can agree with all of the statistical implications of Quantum Mechanics"(2009). However, as mentioned above the field of quantum foundations has always been a rather marginal field of physics, practiced by very small number physicists and philosophers, many of whom fail to acquire a permanent academic position.[32]

Since the 1960s, when Bell's theorem was first formulated, it has become of significance to other areas of physics, as well as in theoretical computer science and information theory. This increased significance, mostly associated with the emergence of quantum information in the early 1990s can be accounted for in a shift of the evidential context and an increased externality of the theorem. Thus Bell's theorem today is of great significance in areas such as quantum computation, quantum teleportation, quantum communication; all of which emerged with or rather constituted the emergence of quantum information. Accompanied by the shift of the evidential context, the meaning and assertion of Bell's theorem changed. Instead of stating the theorem in mere words as above, the theorem is often formulated in context outside of quantum foundations as a purely mathematical statement, often referred to as CHSH inequality, a variant of Bell originals inequality due to Clauser, Horne, Shimony, and Holt (1969):

$$-2 \leq E(a,b) + E(a',b) + E(a,b') - E(a',b') \leq 2, \tag{1}$$

stating that a certain array of expectation values, E(a,b) cannot exceed the numerical value of 2. These expectation values are calculated from measurement results of an EPR-Bohm type experiment, in which two observers - commonly refereed to as Alice and Bob - typically measures the spin of photons. Whereas a,a' and b,b' refers to different detector settings for Alice and Bob respectively.[33]

Missing CTK, used in three of the four categories of cranks, has to bee seen as relative to a community; therefore my proposed schema of cranks has to be understood relative to a particular community as well; which in our discussion of the controversy around Christian's knowledge claim so far was the foundations of quantum mechanics community. However, we have to take into account

that Bell's theorem has significance outside the realm of quantum foundations. The number of researchers, solely working in quantum foundations, the core-set (Collins 1981), is comparatively small to the number of people in other communities, such as quantum information and quantum computation, to which Christian's knowledge claim has significance, if approved. In addition many people work on the interface between quantum foundations and quantum information, often at research institutes focused on quantum information. While Christian has the CTK of the community he belongs to, his tacit knowledge is very limited regarding the quantum information and quantum computation communities.

One example for this lack of CTK of the neighboring disciplines becomes evident in the title of Christian's initial paper: "Disproof of Bell's Theorem..." (2007). In the original evidential context of Bell's theorem this amounts to denying the statement that there is no local-hidden-variable theory, which can reproduce quantum mechanics' statistical predictions. For scientist for whom Bell's theorem is localized in another evidential context, in which it is most often understood as purely mathematical statement, the title is nonsensical to begin with. In this context Bell's theorem is a purely mathematical statement, a theorem, that - per definition of the term - cannot be disproved, as it can be deduced from its assumptions. A mathematical theorem - as long as the derivation is not shown to contain errors - cannot be disproved, at best its assumptions can be challenged. Christian, however, states Bell's theorem in his paper not as mathematical theorem but he quotes the above mentioned definition by Abner Shimony, which reflects his commitment of the original evidential context of Bell's theorem around the quest of local hidden variables.

For scientist outside the foundations community, the title of Christian's paper and the way he introduces Bell's theorem is very unusual; he misses the CTK of these communities on framing Bell's theorem, which, however, is very different from its original evidential context. From the perspective of scientist working in quantum information or quantum computation, but not for people in quantum foundations Christian behaves like a crank, who lacks CTK. One computer scientist describes a feature of such a crank paper, whose author lacks CTK:

> " If someone can't even state the problem correctly, they can't even state what's already known about the problem in any sensible way, then I'm immediately extremely skeptical if they made some tremendous advance on it. That's kind of common sense. If someone can't even state and explain Bell's theorem correctly then I'm immediately very skeptical if they have made some major new inside about it. "

One of the reason why Christian was ascribed crank status is because did not take into account that Bell's theorem is mostly significantly in a context outside of quantum foundations with a different meaning and predication. While the presentation of his paper was sensible to members of the foundations community, it showed lack of CTK for people of neighboring communities. Given that large number of people in foundations community who work on the interface between quantum information and foundations and the small number of people working solely in foundations, the opinion of the research community to which Bell's theorem has significance concerning Christian's work solidifies. When Christian submitted a subsequent article to a high impact journal, it was rejected sight unseen. A member of the editorial board, who processed Christian's subsequent

appeal of the journal decision provides some details about the sediment towards Christian's work on Bell's theorem:

> " The community became very negative [...and] felt that this work is without validity. He was having difficulty even getting a paper to the point of getting refereed. The opinion became so negative, the journal would say - so at that journal and some other journals there is a decision point, where we say: - 'Do we send it to referees or reject it out right?' "

In summary, we have addressed how the foundations community ascribes crank status to one of its members, which amounts to expel him from the community. We identified several sociological contingencies, such as ignorance of the contingent forum and violation of mundane social norms, incongruent self-fashioning and pedagogical deficiencies, all of which take together constituted ground for the community to ascribe crank status. Missing collective tacit knowledge, however, is not among them and thus fails as a universal feature of crank science.

At the end of this paper we want to return to our discussion on the function and scope of the physicists' category of cranks. As the Christian controversy shows, the reflection on cranks by physicists is misleading as it does not take into account cases such as his. In addition to the proposed spectrum of cranks, which represents a first important step towards a more 'realistic' understanding of cranks and how the concept is used by physicists, we want identify an additional aspect of physicists' category of cranks. Given how easily Christian become considered crank and others with similar knowledge claims are not, that there is some awareness within the physics community of the danger of being ascribed crank status.

The Physicists' Fear

In her anthropological account of high energy physics laboratories, Traweek (1992) narrates the progress of a novice to the particle physics community to a full fledged member in terms of "moral tales," one of which is that of anxiety. She assigns different fears to each stage of the aspiring particle physicist,[34] all of which though seem to be a general feature of academics; I argue, however, that there is a cultivated anxiety, that is very specific to theoretical physics[35] related to becoming considered as a crank.

Before discussing this crank related anxiety though, I want stress the importance of distinguishing between work that is being considered crank and work that is mere wrong i.e. it contains a mathematical or technical error. Whereas becoming considered the former has explosive consequences as the case of Joy Christian's knowledge claim vividly illustrates, producing work of the latter category is regarded as almost unavoidable. Most of the physicists have uploaded papers on the arXiv, which turned out to contain one in some cases several, minor or even major mathematical or technical mistakes. Although in rare cases physicist will withdraw their papers, most often when an error is uncovered, a new corrected version of the paper is submitted (arXiv allows to submit updated and corrected versions) Physicist do not proud themselves for producing erroneous papers but the community is aware that mistakes can happen and seems very forgiving with such incorrect papers. A category of publications physicist often refer to is the "wrong, but interesting" paper. A member of the quantum foundations community explains:

" ...a lot of stuff is correct but not interesting, that's even the worse category. I think I prefer to read papers that are wrong and interesting than correct and boring. "

Papers which are "wrong" can nonetheless be interesting, they can allow viewing issues from a different perspective. The interesting, but wrong idea may be easily corrected or used in a different context. Although the correctness of a particular paper is still important for publication in a journal, the questing whether a paper is "interesting" is often much more relevant. Crucial in this context is the consensual character of the term interesting. Physicist do not have to be too concerned about work that is technical incorrect, but they have to be very careful that their work does not become considered as crank science. One of my interviewees, a theoretical computer scientist, working in the area of quantum computing explains:

" Now one thing that you learn - it's a sad thing or it's a cautionary thing for all of us I guess, that you learn being in this field for a while - is that arbitrary smart or educated people can be arbitrarily wrong. There are no guard rails, there is no anti-wrong pill that you take with your PhD. So Gregg Nelson, he is a Noble laureate in physics one of the ... people would know that he is one of the most brilliant physicists in the world. He does not believe in quantum mechanics, he has this idea called [...]. This is something if an undergraduate writes this than you might say this is crackpot, you get an F. It's an absolute terrible explanation, but Gregg Nelson convinced himself that he does not like quantum mechanics. "

The physicist that my interviewee mentions is not an outsider of the community, but one of the foremost authorities. Regardless of his previous achievements, all the work he has published before, his years of training and practice of theoretical physics are almost rendered worthless, because he has become considered a

crank. What is even more ironic about this specific case is, that this physicist has an article on his website, similar to in the physics community well-known Baez crackpot index (1998), in which he explains how to write an for the theoretical physics community appropriate paper. He is aware of the danger of becoming considered a crank, has the highest credentials in the physics community, nonetheless the sub-community to which his work on quantum mechanics is most relevance, considers him as crank. This and other examples which are part of physicists' folk tales[36] indicate the constant threat of becoming considered as a crank that theoretical physicists are exposed to, it alludes that no one in a particular physics community is immune of becoming ascribed crank status.

Conclusion

One agenda of this paper was to show that the structure of the physicists' category of cranks reveals upon closer examination much more diverse than the reflection in the physics community might suggest which often focuses on cranks, outside the realm of professional physics. In summary I suggest to discuss the category of crank sciences as a social technology (Shapin 1994) with strategic properties enabling the physicists for specific tasks:

Delineation: The category of crank science serves the physicists as delineation toll. By ascribing crank status to a particular person, physicists exclude his work from proper scientific work and deny that person entry to scientific community. These aspects of crank sciences reflect the common understanding, that cranks are not professional physicists, who due to their lack of expertise are prevented of contributing to the field.

Expulation: A so far underestimated aspect of crank science is, that it not only keeps outsiders distanced from a scientific community, but also it keeps the community pure. Ascribing crank status acts as a means to suppress novelty within a community, as it represents a category to which a novel knowledge claim and its proposer can be disposed to. Ascribing crank status, as the case of Joy Christian vividly demonstrates, can lead to expelling of the community. This ascription of crank status can be understood as a degradation ritual and aims to suppress any further consideration of a knowledge claim.

Unification: This combination of both tasks is not a coincidence. Physicists, when discussing cranks focus most often only on outsiders of their community, not professional physicist. Such usages of the category crank, reducing the complex spectrum of cranks to a singular category, can be seen as strategic

achievement of the physics community, as only this uniformity of cranks, positioned always outside the legitimate scientific enterprise, renders the attribution of crank status to a member of the community successful. That is withdrawal of membership to the community. Physicist are often hesitant to openly refer to other physicists as cranks, but the mere non-existence of other terms to label cranks within the realm of professional physics further indicates that such label is not necessary, because the only task of such label is to expel. But this is achieved elegantly by singularizing cranks to one category.

Threatening: An additional new aspect of the existence of the category crank sciences is its anxiety creating structure. The danger of becoming considered a crank in the eyes of ones colleagues is encultured in the theoretical physics community and helps to keep the community uniform and further supports novelty suppressing tendencies.

Notes

[1]Only recently the contemporary practice of theoretical physics has been studied Kennefick (2000), Merz and Cetina (1997), Reyes Galindo (2011). There is, however, literature on the historical practice of theoretical physics, for example: Kaiser (2005), Olesko (1991), Seth (2010), Warwick (2003)

[2]For the history of the foundations of quantum mechanics community Freire (2004; 2006; 2009) and some work in the sociology of scientific knowledge Harvey (1980; 1981), Pinch (1977; 1979)

[3]Although the case study is focused on the foundations of quantum mechanics community, we assume that our findings are not limited to that particular community, but can be applied to the wider physics community and with some limitations to mathematics and theoretical computer science.

[4]Compare Collins realist approach towards expertise

[5]Reyes Galindo (2011) provides a more detailed discussion of various criteria that physicists name to recognize crank papers.

[6]For a discussion of the role of the arXiv see Bohlin (2004), Gunnarsdottir (2005), Lynch (2005).

[7]That some scientist would submit their papers to journals only to improve their career chances or those of their students and post docs or to attract grants suggest that Collins and Pinch (1979) distinction between contingent and constitutive forum has to be extended to another category: the forum, in which scientists improve their credentials. In this extended fora schema publication on the arXiv can be seen as the constitutive forum, wheres the journal is an example for this credential forum.

[8] For a discussing whether physicists actually read papers and to what extent see Collins (2007).

[9]The rule of the thumb is that papers, which a journal would sent out to for peer review are eligible to be published on the arXiv. There are, however, more specific rules (quote arXiv).

[10]A detailed discussion of arXiv's delineation technology would be desirable, but is well beyond the scope of this paper

[11]The term crackpot is frequently used in the physics community synonymously with the term crank.

[12]The term professional physicist in this context does not entail that these people receive an income of their work in physics, but refers rather to people who are embedded in the scientific community.

[13]Especially the connection between CTK and Collins and Evan's realist approach towards expertise (2007), for example highlighted by Doing (2011) and Reyes Galindo's (2011) discussion of and reference to Weinel (2007; 2008)

[14]This temporal stability, however, can be questioned. Beller (1998) give convincing examples of the founders of quantum mechanics who were heavily invested in what is today considers outside the realm of legitimate science (at least if one follows in what some proponents of the 'Science wars' suggest, see also Labinger and Collins (2010), Shapin (2010) in this context). Brush's (1980) concept of changing periods of Realist and Romantic in science and society might be able to provide a more detailed description here.

[15]This, however, is a very simplified narrative of the history of the field of quantum foundations. For a more detailed discussion see Bromberg (1997), Brush (1980), Freire (2004; 2006; 2009), Kaiser (2011). One aspect of the history of the foundations community worth mention - with hindsight to some of of the measures taken against Christian in the course of the controversy - is the narrative of some early members of the foundations community reflecting on their own past and their struggles with the quantum elite:

> " Bohr's authority together with Pauli's sarcasm killed any discussion (Zeh, 1980)
>
> Religious stigmas and social pressures that taken together, amounted to an evangelical crusade against thinking about the quantum foundations (Clauser, 2002)
>
> ...through repression and control of positions and publications. And then also a lot of dogma exists (Selleri, 2004)
>
> the Copenhagen line was 'scientific', anything else was meaningless, mumbo-jumbo, or, at best, mistaken (DeWitt)
>
> unchallenged monocracy of the Copenhagen school (Jammer, 1974) "

What is remarkably about this narrative, is that it takes for granted that science is not enterprise which is apolitically. Further it does not focus on an intellectual battle between people working on foundations and the quantum elite that was won by the latter due to their power and influence. They instead entirely focus on the 'political climate', which made even thinking about the foundations of quantum mechanics impossible to begin with. It would be interesting to apply the same 'method' in analyzing the controversy around Joy Christian that the foundations community employs to narrate their history: an approach which is fairly ignorant towards any seemingly apolitical, 'scientific' argument. Assessing the quantum foundations community in the same way as they assess the quantum elite seems a very natural way to approach this task, similar to the reflexivity component of the strong program in the sociology of scientific knowledge.

[16]By some of my interviewees regarded as the most successful theory of quantum gravity so far

[17]The name of the author, tile of the book and publisher was changed for the sake of anonymity

[18]The foundations community seems to maintain a revolutionary narrative of their own history, pictures themselves as victims ,often research in foundations is depicted opposed to "physics properly" or "straight physics" Christian describes the tension between the self-fashioning of the foundations community and their actual reaction towards his paper:

> "There is one word I always wanted to mention yesterday, but I forgot in our discussion about my immediate experience at [the research institute]. The word is hypocritical. The attitude there from people in foundations was very hypocritical, because they were constantly criticizing the string theorist and the other people doing other things and saying like: 'They don't question the fundamentals.' But when their fundamentals were challenged - by me, they behaved exactly or actually even worse and some string theorist actually noticed that: 'How can you react in the same way and becoming so dogmatic when your basics principle is challenged?' And it is not challenged in a crackpot way, because my paper is clearly a solid

piece of work. You may disagree with it, that's another matter but it was more than disagreement, it was a very negative reaction, dismissive and intolerant reaction. They could not see that at all, they did not realize that they were reacting as dogmatic, as close-minded, intolerant people.

"

[19]This institute with no physical research site, was funded by the Templeton Foundation and set up to support what is described as high-risk research, which would not receive funding otherwise.

[20]as the second version of this paper (Pawlowski 2007a) is identical to the first one (Pawlowski 2007b), except the authors, we assume that the influential theoretical physicist Marek Zukowski withdraw his authorship

[21]Whether Christian has actually published papers was denied by some of my interviewees, while some explained that a paper on the arXiv is published "for all practical purposes", consistent with Reyes Galindo's findings (Reyes Galindo 2011). The question whether it would make a difference in the Christian controversy were the papers published in peer-review journals might be interesting, however, doubt seems not unreasonable

[22]as of Spring 2013 Christian has published 14 papers on Bell's theorem on the the arXiv: Christian (2007;?; 2008; 2011a;b; 2012a;b; 2013; 2007c; 2009; 2010b; 2011a; 2012a)

[23]The book finally appeared in Spring 2012 (Christian 2012)

[24]Interestingly enough the moderators of the arXiv, which rejected one of Christian's reply to a critique months earlier based on inappropriate language, did not object Gill's paper for the same reason. As the arXiv does not enclose any information concerning the rejection of papers for particular cases, the account of arXiv's moderators decision here and below is based on the information provided by Joy Christian

[25]FQXi's mission statement: "To catalyze, support, and disseminate research on questions at the foundations of physics and cosmology, particularly new frontiers and innovative ideas integral to a deep understanding of reality but unlikely to be supported by conventional funding sources." It further states: "FQXi therefore aims to support research that is both foundational (with potentially significant and broad implications for our understanding of the deep or 'ultimate' nature of reality) and unconventional (enabling research that, because of

its speculative, non-mainstream, or high-risk nature, would otherwise go unperformed due to lack of funding)." (FQXi 2009)

[26]the name of this researcher, as well as all others were change

[27]That the above stated norm can be seen as quite universal illustrates a historic example from England of the 16th Century. Sir Walter Rayleigh (1554-1618) lost the favor of the Queen, because he secretly, without informing the Queen, married his wife. citepmatthew2004oxford and personal exchange with Mark Nicholls

[28]Comment on the mainstream of foundations

[29]This mathematical formalism, as its proponents argue, is a powerful tool which would allow to describe every subfield of physics, with a unified, geometrical language. Hestenes publishes a book in the 1960s and subsequently starts, as he self describes, "a sociological experiment", submitting twelve proposals to the US National Science Foundation, all of which were rejected, although praised by a third of reviewers, a third, as Hestenes explain, reject his proposal outright as crank science (Hestenes 2003).

[30]Christian provides detailed step-by-step calculations on various blogs where his papers are discussed

[31]according to an argument by Einstein, Podolsky and Rosen (1935), for a detailed discussion of the sociology of paradoxes see

[32]among them Joy Christian, for further discussion of such physicists, who often continue with physics on their own time and expenses see (Smolin 2008)

[33]The first experiment was performed by Holt and Pipkin in 1972 (Holt 1973), which did not exceeded the value of 2, hence contradicting the quantum mechanical prediction. Most of the following experiments, however, confirmed the quantum mechanical expectation value. For a sociological account of the discussions around these early experiments see Harvey (1980; 1981). The nowadays first successful considered experiment was done by Freedman and Clauser (1972), subsequent experiments followed, all of which tried to close some loopholes: prominent examples are Aspect et al. (1981) and Weihs et al. (1998); experimental efforts are ongoing to close all loopholes: Giustina et al. (2012)

[34]these fears are: "fear of accomplishment of others, fear of losing present time, fear of the future coming too fast" all of which are "inwardly experienced", but nonetheless "learned and cultivate in the community."

[35]the concept of cranks has relevance in other 'theoretical' fields such as mathematics or theoretical computer science as well

[36]among them the Albert Einstein, who become considered a crank as he refused to give up his arguments against quantum mechanics check that and check reference

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