

Numberphile Podcast Transcript

Episode: The Little Star - with Zvezdelina Stankova

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Mathematician Zvezdelina Stankova was born in Bulgaria and is now a teaching professor at UC Berkeley.

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[Gentle Violin Music]

Brady Haran [BH]: Today's guest is a regular and very popular contributor to our Numberphile videos, Zvezdelina Stankova. Zvezda, as most people call her, is based in Berkeley, where she's heavily involved in helping the next generation of mathematicians through programs like Math Circles and the Math Olympiad. Zvezda herself was a star Math Olympian for her native country of Bulgaria where she famously solved a fiendish problems that's been written into folklore, but we'll come to that later.

[Gentle music box music]

BH: Let's start with your name, because I call you Zvezda but that's to your full name.

Zvezdelina Stankova [ZS]: No. My full name is Zvezdelina.

BH: Okay.

ZS: And that means... little star.

BH: Little star?

ZS: Yes.

BH: I like it, alright. Tell us where you were born.

ZS: I was born in Ruse in Bulgaria. It is a town on the Danube River. That's where I grew up.

BH: And what was childhood like in Bulgaria? I've never even been to Bulgaria.

ZS: I have very sweet memories from my childhood even though it was during the Communist Era. My parents were very involved with us, the kids.

BH: So what were you like as a little girl then? Were you into mathematics very early?

ZS: Not until fifth grade. I remember the particular moment that turned me towards mathematics before that I was doing quite a lot of things, playing the piano, doing ballet, I also wrote poetry. I went to a poetry circle and I even won some competition with a poem. So I was all over the place... in seventh grade I even participated in a chemistry olympiad and I won it to my surprise but it was because of my math knowledge. That's a different story. Math came to me probably in fifth grade, until then I was getting As in math but not really living up to my full potential and so I remember one day in fifth grade the teacher called me and another girl to the board to give us an oral examination that was a very standard practice. Each of us got a problem and we had to solve it on the board, the class knew our problem so everyone else was also working on them. The other girl solved her problem and went back to her seat and I couldn't do my problem. It was about some ship and a boat going up and down a river and I had to create a simple system of two linear equations and solve it. And I couldn't and it became apparent to me that I had not been paying much attention to my classes lately. So the teacher left me there at the board for the rest of the class. She started the new lesson, she taught it from her desk, but I was there for the rest of the class, I was so distraught, I was crying towards the end and so the bell rings and she calls me to her and says, Zvezda do you know what grade you deserve? And I said yes I do. Well, I'm not gonna give it to you if you come tomorrow with the correct solution and explain it to me very well. So I went home and I thought to myself, gosh am I really the stupidest person in class, because what happened is the rest of the class solved my problem and that's why the teacher moved on with the lesson. It cannot be that I'm here, the last, and

this probably was not such a hard problem, so my father is a shipbuilding engineer, as it happens. So, we sat down in the evening, he explained everything to me, the next day I went back, showed it to my teacher and she said, okay, you escaped this time. You're not gonna get the bad grade. But I didn't leave her side, I asked her, can I join your math circle? She happened to be the teacher leading the math circle in my middle school.

BH: What is a math circle, for people who don't understand?

ZS: So it is an after school program, it was twice a week at that time for an hour and a half and we were solving problems that were related but somewhat beyond the school curriculum and sometimes we would even be taught new theorem. The math circle both prepared you for math competitions but it also expanded your math horizon.

BH: And why did you want to join the math circle? You'd just been humiliated, you gotten off the hook, what made you want to go deeper and further? I would've thought you'd want to avoid this lady, now?

ZS: Oh no, I actually took everything completely differently. She gave me a second chance and I very much respected the teacher. So the problem was not with the teacher, the problem was with myself and I realized this even at that early age. I also knew that my classmates who had been going to the math circles for several years were performing very well at the local math olympiad. So I thought maybe the circle will help me with my performance in class too. What actually happened is three months later I won first prize at the local math olympiad and that settled it. [laughs] All of a sudden everything else was secondary.

BH: I can imagine some fifth grade students, if been told you're gonna get a bad mark, you've failed, this particular assignment, they would just say, oh well, I'll take that on the chin. It feels like even at a very young age you had some kind of drive or competitiveness, is that correct? Or...

ZS: That I'm very competitive, this is true, that I had already competed at events in other areas, it is also true, I think I had a very hard time taking defeat. I couldn't fall easily.

BH: Where did this come from? From your parents, or...?

ZS: Probably. My mom also won a competition to study abroad and this was deep back in the Communist era, which was quite rare. And my grandmother actually was accepted to the math department in Sofia University. She ended up studying German. So I think I had it all from all sides. My father came from a very small town where there

were no conditions for him to study anything but violin, so he played violin when he went to the Naval Academy but he also helped all of their classmates cheat on their exams, don't tell anyone, on their math exams, so I've heard quite amazing stories. So, I was getting this math, engineering drift from all over the place and everyone in my family had succeeded to one event or another. One of my grandfathers had the ambition to move to a better place for his family. My father's father. So they moved from this very small backwards village, which I still like. They move to this little town and they had no money to build a house. He made the bricks with his barehands and he build the house. Well if he could do it, I thought I can also [laughs] do well on a math competition.

BH: So at this sort of fifth grade time, you've joined a math circle, you've had a success in a competition, if I'd come to you now, you know, and said to the young Zvezda, what do you want to be when you grow up? Would it have been mathematician now, were you already thinking, this is what I want my career to be or how did you see your future at this point?

ZS: I think at this point I didn't have a choice. For me, a door opened. The fact that only after three months of being with this math circle teacher really made me wonder why I had not joined the math circle before. But that meant I had to gradually start dropping other things. I remember in seventh grade, the whole year, I took extra lessons in writing essays because I wanted to get into the English language high school. Not that math high school. That's the interesting part. I knew I could do the math by myself but I also knew that I was not good with languages. So, there was an entrance exam in math which I wasn't worried about but also in writing an essay in Bulgarian and I knew that they were very harsh in grading it. There were about twenty girls per one spot, the boys were given little bit of affirmative action [laughs] 'cause they were fewer of them applying and an equal amount of spots. At any rate in seventh grade I realized that I had to drop certain things. So I stopped playing the piano and dancing ballet and I cried for two weeks straight. I remember that. I just return home and I felt empty. I felt empty. And to this day when I watch good ballet performance I'm about to cry thinking what could have been. But I didn't have a choice, for myself it was never a doubt in me that I would continue doing something with mathematics since that day in fifth grade.

BH: Why not... so you had to give up ballet just 'cause of time constraints? It was like just a...

ZS: Yes, that is true.

BH: Yeah.

ZS: Yes, yes. Time... both ballet and piano. I was determined that I had to enter the

English language school, maybe at that point I thought that I was going to study abroad, it was inconceivable for kids in a socialist country to think that way. The furthest I would go probably would be Russia and you don't need English for that.

BH: Hmm.

ZS: I had a specific problem with writing essay and the problem was I didn't... like to write essays. I was really good but it was not my passion. And still my drive would be I have to make it perfect. I have to make it the best so I would spend, you know, weekends preparing and writing these essays. Later on I found actually that it was super beneficial for me. So studying languages, writing essays, but I was doing math because I wanted to do it.

BH: You mentioned they had a different number of places in school for the boys and girls, that was just culturally acceptable was it?

ZS: Oh no, no, they wanted to make it an equal amount of boys and girls, so since there were more girls applying than boys, they had to, you know, give a little bit of affirmative action and also at that time the tradition was to put all of the scores out there. Everyone could see everyone else's score. And when you compare the entrance score of the girls versus the boys, [laughs] the girls would beat them up fair and square. In the math exam the difference was... not very palpable but in the essay part it was. Now if you look at the math high school, the situation was reversed, there were more boys than girls... who were applying.

[gentle piano stinger]

BH: So many mathematicians I speak to talk about during their school years mathematics was kind of, you know, a bit functional, a bit boring and it wasn't until they got to higher education that sort of the door opened to the beauty of proof and things like that. Was that the case for you or were you already seeing mathematics as a beautiful thing, like an artistic thing?

ZS: Okay, we started learning proofs in fifth grade. [chuckles]

BH: Right.

ZS: That same fifth grade, so every problem we had to prove that our solution was correct. To supply the evidence and of course we started with some baby steps. I never saw this two column format proof in geometry, that's super restrictive, so from an early age we were really taught to approach problems like mathematicians and this continued all through high school.

BH: Was this because of the high school or was this because of the extracurricular math circle work you were doing?

ZS: Neither. It was because of the government. The government had a program that was uniform for all schools. It is true that in the English language school and math high school certain subjects were taught better and they were higher demand on the knowledge and skills of the students but uniformly throughout Bulgaria everyone had to learn a certain curriculum and proofs were included in it. The math circle of course expanded my knowledge well beyond what was the curriculum. But in high school I have to tell you almost never sat in a full math class or even listened to what was going on. I had the math contest book under my desk on my lap. I was just doing that and the teacher just did not bother to examine me at that time 'cause I was just going to contest and math olympiads. She even asked me to grade some of the final exams but not or my particular classmates but for the classmates in the next room, so it wasn't that bad. So while my classmates were taking an exam, I would be grading the exams for another class.

BH: [chuckles] And you were just a schoolgirl at this point?

ZS: Yes. Yes.

BH: [chuckles]

ZS: You know this practice actually is happening here in US with... because there are quite a few advanced students who literally have nothing to do in math classes so they ask them to tutor, to help with grading exams, and so on. It's not good though to ask a freshman to do this for the seniors, some, you know...

BH: Yeah.

ZS: Things might happen to you outside of school. [laughs]

BH: Okay. So you're obviously an exceptional high school student in mathematics, what happens next? How does your path continue? What's the next big step?

ZS: I went to the International Math Olympiads in Cuba, in Australia, and before that I went to one of the Balkan Math Olympiads in Romania, as a representative on the Bulgarian team, and those olympiads really defined my day, month, whatever I was doing it was geared towards helping me perform there very well but also qualify on the team. The competition was very fierce and as you might expect there were more boys than girls, so we were outnumbered by a lot.

BH: Was your drive about these olympiads because you're just competitive and wanted

to win a gold medal and stuff or did you see this as being important to your career and your future? Or was it just purely like, you know, your competitive nature?

ZS: You know... I had no clue that performing well at any of those olympiads would give me a scholarship to come to US. That came later. I was also given the opportunity to compete in chemistry olympiads as I told you. In seventh grade my chem teacher came to me two weeks before the local chemistry olympiad and said, would you like me to prepare you to take the olympiad? And I said, but I'm not like really interested in chemistry. She said, that's okay I'll teach you what you need to know from that but you know the math and that's what it will boil down to, and she was right. I won first place at this chemistry olympiad with just two weeks of preparation from her but it was not my interest. I could have continued... I just didn't feel any drive to it. Geometry specifically was my most interesting topic in mathematics. That's where my imagination grew but of course there are so many different math areas that came up there that I could carry on in my college studies.

BH: So tell me about those two olympiads, the first one was in Cuba, how did you do? What medal did you get in Cuba?

ZS: Oh I got silver medals on both of them.

BH: Alright.

ZS: I dunno how fair this is to say but it was harder to get a gold medal then. Why? Because there were fewer countries and those were very strong countries and again no disrespect to any countries here but those were the founding countries of the olympiad, plus, US, Canada, those were getting really strong too.

BH: Hmm.

ZS: It was hard to get a gold medal. A silver medal was enough for me especially solving the last sixth problem on the second IMO really sealed it for me.

BH: Okay let's talk about that. I think people who watch Numberphile will know about this already. We've done a video about this famous question six at the 1988 olympiad which was held in Australia. The famous mathematician Terrence Tao was there as child prodigy. He couldn't crack this problem. But you famously did crack this problem along with another one of your Bulgarian colleagues and that was your crowning achievement, was it? At the olympiad?

ZS: Yes. It was a very dramatic moment for me there because I had not slept the previous night. I had not adjusted to the jet lag. I was completely exhausted entering the

second day of the olympiad so I knew that I had to do it fast, do it well, and go to sleep. Shall I tell the story? [chuckles]

BH: The full story will be in a Numberphile video for people to watch but this was a quite an achievement that you were able to crack at and your success at that started opening other doors did it?

ZS: Yes. So that problem, the sixth problem was solved by probably twelve people and two of them were Bulgarians, I was I think the only girl who solved it.

BH: Sorry how many were Bulgarians?

ZS: Two Bulgarians solved that problem, Emanouil and I, and the points on this problem were either sevens or zeroes, something like that, so it was either all or nothing. I mean you cannot chop up this problem in half. So to speak. But I do remember I spent at most twenty minutes on that problem and I had seen vaguely similar stuff to it and its not really the same problem but the idea of somehow creating similar problems to solve that problem and this is how the solution goes. You have to look beyond what is given, create more problems in order to solve that particular single problem and that kind of grand idea is what probably gave me advantage in this problem even though it's a very generic idea.

BH: Do you think in hindsight that was too hard a problem to be giving to the kids?

ZS: No! Twelve people solved it so that's [chuckles] it was definitely number six in its correct place so it was...

BH: The last last...

ZS: Perfectly pitched.

BH: Okay.

ZS: For that spot.

[gentle chimes]

BH: We'll take a quick pause at this moment for me to tell you I've recorded a new Numberphile video with Zvezda going into much more detail about this legendary question and how it was solved. That video should be coming out in the coming weeks or month or two once we have it all edited and ready for you. In the meantime we do have a great video about question six already on the Numberphile YouTube channel. That features Simon Pampena and I'll link to that in the notes for today's episode, so you

can go and check it out. Meanwhile can I also quickly thank today's episode sponsor, that's G-Research. G-Research is a Europe based leading quantitative finance research firm. They hire some of the brightest minds in the world to tackle the biggest questions in finance. That expertise is combined with machine learning and big data, all that kind of stuff, the most advanced technology available to predict movements in financial markets. They're always on the look for top talent, who knows, you out there listening, you might be their next recruit. To find out more about joining G-Research, their great environment and conditions they like to create for employees, go to gresearch.co.uk/ numberphile, I'll also put that link in the notes. But now... back to Zvezda who's just cracked the legendary question six.

[gentle toy piano]

ZS: So that summer in Australia, the American team... they were only boys at that time, walked around in white t-shirts and asked anyone to write something for them. And we thought, wow they're destroying their t-shirts but okay. [laughs] And so, I picked a pen and I wrote, "I want to go to study in US."

BH: You wrote that on his t-shirt?

ZS: Yes, and I know the boy [laughs] afterwards at Harvard we ended up in the same program on whose t-shirt I wrote this. And my teammates looked at me and started laughing and saying, okay you can keep dreaming. Of course this was back in Communist times, there was no opportunity for us to go to US much less so study. So I went to Sofia University, right after that summer in Australia and the moment I started climbing up the stairs to my department, because you apply to a department, I was in the math department, I saw a poster announcing a competition to study in the United States. And I knew that there would be thousands of people applying like everyone would apply and initially I was not interested in applying because I thought that this would be a waste of my time, that there would be some political concerns there, whom to send, whom not to send, and I didn't have any particular connections... so... I didn't apply. My roommate actually was very pushy, she was also my high school classmate, and she said, Zvezda, you apply or I'm not your friend. And I did. [laughs] And... it was a sequence of tests. Some tests in English and there you go, I went to an English language school so that paid off. We had a dictation. A dictation in English, to see how we can write, how we can understand.

BH: Mhm.

ZS: And it was from my favorite science fiction book as a child. The Day of the Triffids. It starts in a hospital with a guy whose eyes have been bandaged and he's waiting for someone to take them off and no one comes. So the moment [chuckles] the lady started

to reading this sentence I knew I would do it well because I knew what was happening even though I had read it in Bulgarian. There were some psychological tests that they put us through, but somehow the people and the students from math and computer science were answering really well. We could see what the committee wanted us to answer and there we went so in the final fifteen students at the last round, at least half were from math, computer science, and this is a large university. And at the last round the Bulgarian foundation who were selecting us had to yield to the American embassy so they make the final decision. The American embassy were very clear that we are not going to let this go to unqualified students with connections, for example.

BH: Hmm.

ZS: They have to be qualified. And so here we go fifteen of us knowing that there are only seven scholarships. That's the dream... of so many... students. Finally it's made public, and I was thinking gosh what are they gonna ask me... those Americans, so we entered the American embassy, and you imagine this is the first time I'm entering... I mean I had been to Australia, so another capitalist country but I was never inside the American embassy. And so they called us one after the other. And you know what question they asked me? What's your favorite movie? And I said Indiana Jones. Why?

BH: [laughs]

ZS: And I really had to tell them. [laughs]

BH: [laughs]

ZS: That was the whole interview. [laughs]

BH: That was all they asked you?

ZS: Yeah! Some very friendly people there.

BH: Yeah.

ZS: They read all of the test results. They read about our accomplishments and then a week later they published an article that all fifteen students were so good they're gonna find more eight more scholarships. [laughs]

BH: Oh great, you all got in.

ZS: And so... yeah so we all got in, all fifteen.

BH: Did your performance in the Olympiad help? I imagine that was a part of your CV,

it was part of the...

ZS: I think that that was the major item that...

BH: Hmm.

ZS: ...put me in the front runners. I heard that the Australia committee, some people on the Australia IMO committee had remembered what I did on the IMO problem number six and so they wrote to the Bulgarian committee about it.

BH: Why did you want to go to America?

ZS: You know... there were all of these restrictive rules about residence in Communist Bulgaria. It was for example very hard to live in another city at that time. I had no drive to just restrict myself to live only in my hometown. I always wanted to see the rest of the world and I was already given opportunity to go to Cuba and to Australia when my classmates could barely go to maybe Romania or Russia. And so I already saw some other parts of the world and once you see them you want to see more. You want to explore.

BH: So, where did they send you? And what was it like for a quite young Bulgarian woman to suddenly find herself in the United States?

ZS: It was tough. It was... in the beginning it was very depressing. It was a cultural shock.

BH: Where were you?

ZS: I was at Bryn Mawr College which is a small women's college near Philadelphia. Now don't get me wrong, it's a beautiful place and my professors were super supporting. I learned tons there but the beginning was tough. I felt isolated. I felt literally without any anchor throughout the first year.

BH: Did you think you'd made a mistake?

ZS: [sighs] No. I didn't make a mistake. I was trying to figure out what to do. [chuckles] How to make it work for me. One thing that was very hard and I had not realized this before coming to US, was the way US higher education is organized. I went to a liberal arts college, which asked me to take classes outside of mathematics. Can you imagine me taking classes outside of mathematics? I had already been for one year in Sofia University. What classes did we take? I didn't have a choice there. We took, first semester, linear algebra one, real analysis one, abstract algebra one and discrete math one. We took algorithms, some Russian, history of Bulgaria Communist Party and

Physical Education. Not everyday but... what did we do second semester? Part two of all of those and that curriculum alone already constituted two years of what a math major in the United States would be. We were not doing any sciences or Western literature or humanities, none of this, you had to apply for a department.

BH: So in American where you now have to do some of these other subjects which are quite alien to you, what ones did you choose, and how did you find those?

ZS: I tried to be smart about it, in the midst of being very depressed the first few months, so I took... methods in... was it... uh... statistical methods in micro-economics, which turned out to be mathematics.

BH: Okay.

ZS: I also took deduction and logic which turned out to be mathematics. In both of those classes I was asked to hold problem solving sessions to help my classmates and I was astonished, I said I'm not an economic majors, I'm not a philosophy major, you are kidding me. And they said, no, no, no, you know the math and that's what's really counts. So I tried consciously or subconsciously to avoid anything that was completely not math, except I took French. [laughs] I did that. And um...

BH: Zvezda, do you feel like... that young woman who was like so steeped in mathematics and at university had just done mathematics and now comes to America and is offered these new things but she still just wants to do mathematics, like that obviously shows a passion, but do you think it was making you a well rounded person? Do you look back and think, you know, I was too obsessed? Or do you look back fondly and think, I love how obsessed I was.

ZS: [laughs] I don't think I would have done it any differently because you had to take into account my psychological setup. In high school we did all of that. We did science starting from sixth grade with labs. We wrote those essays that I took so... so when I was going to Sofia University and you apply to a specific department, you are done doing this rounding things, so when I came to US I wasn't prepared that I was gonna backtrack several years and start all over again.

BH: Okay.

ZS: [laughs] But let me give you one small detail, don't tell anyone, ooh they are listening to us...

BH: [laughs]

ZS: How did I pass one of the humanity requirements? Okay, I went back to Bulgaria

the first summer to Sofia University and I asked for a syllabus of the class on history of the Bulgarian Communist Party.

BH: Right?

ZS: And they gave it to me, it was a serious class, not that I cared much about any of this, and I went back to Bryn Mawr and presented it to them and said, maybe that would waive one of the requirements, and they wow, you are only local specialist on that topic, of course, and they did the check mark.

BH: [laughs]

ZS: [chuckles] And I didn't end up taking that. But I did take the freshman or should I say freshman class in English. So that was a year long class, you would get a grade the first and then the second semester and that was primarily to teach students how to write the essays.

[gentle chimes]

BH: How long were you supposed to spend in the United States? I'm assuming it was a finite time and you were supposed to go back to Bulgaria?

ZS: I mean there was no supposing. I didn't have any funding. Even the tickets were paid by that foundation. I have to earn my pocket money by being in the cafeteria or grading papers or something like that. So yeah I was supposed to go back to Bulgaria after four years but what the Bulgarian foundation was already predicting is that because these fifteen students were so strong to start with they would probably go onto graduate studies and this is what happened to most of them.

BH: So you went on to do graduate studies. Where did you do that?

ZS: I went to Harvard.

BH: Oh wow, so you, obviously you were doing well. [laughs]

ZS: [laughs] Yes, it's amazing that from a small liberal arts college like Bryn Mawr I went to the father of all universities in US, Harvard. [chuckles] Father and mother, the parent, but it is not so amazing because... as I said my professor at Bryn Mawr really really supported me. They could see how I was different from many of the others, of the other students.

BH: How were you different?

ZS: I wanted to do only math, right? I told you.

BH: Yeah.

ZS: And that was very different from the environment around... I did benefit though from that English class, I can tell you. [laughs] And from the deduction, logic and philosophy but one thing that really made it possible for me to be accepted, probably in any graduate program in the United States, was the research experience for undergraduates that I did for two summers while I was at Bryn Mawr. I went to Minnesota, Duluth, and that was a very tough program to get in. Joe Gallian is the director of that program and he and the other people at the program helped me tremendously. I wrote research papers on open problems and that's what I think got it for me.

BH: What was your ambition at this point?

ZS: I... wanted to do something with mathematics and most likely it would have to be in academia and most likely a professor but my first year at Harvard was a fight for survival. Because I did not know some of the topics that were sort of assumed of the graduate students there. Like algebraic geometry. I knew nothing whatsoever about algebraic geometry because those topics were not taught at Bryn Mawr but it seemed that everyone around me in my class knew everything in every single topic course I would go, questions would be answered immediately and I'm just sitting in the background thinking, you know kind of back to fifth grade, am I really the stupidest person here or probably I just had not been introduced to those topics before so I studied so hard that first semester. And when the finals happened I went to take them, two of my professors contacted me and said Zvezda can we copy your final as the solutions for the others? I said no, no, no you have the wrong person. [laughs] I was probably the only one who knew nothing about this, but they said yeah but you learned. [laughs]

BH: [laughs]

ZS: So it paid off this very hard work, so I wasn't thinking about what I would be in the future, I was just thinking about surviving that first year and I did it. Then after that, after I started working on my PhD thesis with Joe Harris, another Joe in my life, it was a completely different type of experience for me.

BH: How was it different?

ZS: Well, you don't have to anymore [chuckles] study all of these different topics. You are more goal oriented. And Joe Harris had a very nice approach with students. He

would feed us, at least me, every week a new example of a phenomena that I was supposed to solve. And every week it got more and more complicated but gradually until at three A.M. one morning [laughs] the light dawned on me, what was happening. So this process was more directed as opposed to spreading myself and studying different topics which I liked.

BH: Because that sounds like quite a change of pace for you, who seemed to all that time just absorbing more and more diverse stuff like a sponge and competing and getting grades and that and suddenly it feels more like a leisure but deep experience.

ZS: So I think that the expansion, the true expansion happened in middle and high school for me where we were studying... I was exempted from math classes [chuckles] but not from the others [laughs] so we were really absorbing a lot of material that was not necessarily mathematics. All sorts of stuff. And when I went to college I wanted to narrow it down only to mathematics and when I went to graduate school narrow it further down and guess what the area of my thesis was? Algebraic geometry. The one that I knew absolutely nothing about when I entered. So that's, you know, the kind of person I am. If you... challenge me with something it's very likely I'll rise up to the challenge if... I like it. [laughs]

[gentle chime music]

BH: So as you start finishing your PhD, do you dream of becoming one of these mathematicians who, you know, publishes great proofs and has their name attached to things or were you dreaming of becoming like a teacher and a great imparter of knowledge? Did you have an idea what kind of math professor you wanted to be?

ZS: I never really dreamt of proving any big theorem other than Fermat's Last Theorem and that was done. [laughs] But teaching became slowly and gradually my true passion. Teaching mathematics. Imparting mathematical knowledge. Probably because I was so fortunate to receive great teachers. Starting with my fifth grade teacher in math and going all the way to Sofia University. Great teachers who cared about me and who very selflessly gave everything they had to me and my teammates on the math circle team.

BH: So once you've got your PhD what kind of academic do you become?

ZS: Let's backtrack the last year at Harvard, I had already solved my PhD problem so I was just writing technically the thesis and wrapping up some loose ends, but that last year I entered the Harvard Graduate School of Education program for a certificate. And I was thinking that I wanted to do a math circle in US. Math circles were not known in the US at that time. I think there was a Boston circle that started in 1993 but I wasn't even aware of it at that time. So I wanted to start a math circle but I was also aware that

a postdocs with PhDs in math are not really gonna be allowed to go and teach anything in school. [chuckles] You need something more than just your PhD. And so I went through this very rigorous education program on top of my regular math graduate program at Harvard that last year and got a certificate to teach in public schools in Massachusetts.

BH: Hang on a second, you're telling me a PhD in mathematics is not enough to be allowed to go and teach in a school.

ZS: Not in a public school system. No.

BH: Right.

ZS: I don't think so. Yes you will have a teachers in private schools who don't have this teaching certificate.

BH: Right.

ZS: But public schools, no. There are rules about this and when I came to Berkeley, I enrolled in the program here at UC Berkeley so that I could get a teaching certificate in California.

BH: So what brought you to Berkeley?

ZS: Well that's where I got a postdoctoral fellowship first at MSRI and then at UC Berkeley.

BH: Okay.

ZS: But to tell you the truth I never used the actual teaching certificate for anything.

BH: Right.

ZS: Other than a general understanding of how education works in the US, 'cause I was quite blindfolded by [laughs] around that time.

BH: So you are here in California now as like a postdoc mathematical researcher but you're starting to evolve these ideas about education and teaching at the same time?

ZS: Yes. In fact it was at MSRI many years ago, '97, that was the year I came to California, that I talked to David Eisenbud and Hugo Rossi. Hugo Rossi was then the deputy director of MSRI. And we had several events to explain to the general... audience... general public here, what is a math circle. During one of those conferences at MSRI, I think it was in April 1998, there were about maybe thirty to fifty teachers

from local schools, so we gave demonstrations what math circles are. We talked about how to organize them. Everything went great and then I had the crazy idea to check how many teachers would be starting a math circle next year. Please raise a hand. Guess how many hands went up?

BH: Not many?

ZS: Zero.

BH: Yeah.

ZS: And the reason for that is that the teachers were A, overwhelmed with their work and B, they needed the model, they did not... were not prepared to teach for a whole year a math circle on...

BH: Hmm.

ZS: ...what they did not know what they were supposed to teach.

BH: From my experience a lot of high school teachers just are overwhelmed with what they have to do, yet alone extra stuff.

ZS: Exactly. But they were willing to see... what a math circle is, and maybe to participate if someone else organized it.

BH: Okay.

ZS: And so I that very conference I asked... seven of my colleagues, so eight total, mathematicians, would you like to help me start an example, just a demonstration for one year.

BH: Like a pilot.

ZS: Pilot, that's right.

BH: Hmm.

ZS: But not a pilot, it was supposed to terminate after one year.

BH: Okay.

ZS: It was truly going to be one year example, the teacher's would be coming, sitting in the back row. There would be actual students in the fronts rows and the teachers will

collect topics and then they would go and do it in their schools.

BH: Hmm.

ZS: The circle started in 1998... nine? It's still running. [laughs]

BH: Right.

ZS: This is the twenty-fourth year of the circle.

BH: So it's not based at any one school is it? It's kind of like a hub that students from various schools all feed into?

ZS: Yes, yes. So we have students in the pre-Covid times from Sacramento to San Jose, Palo Alto all the way to Danville. So this is this expanded Bay Area, San Francisco Bay Area. And they would come every week, in the evening, would travel, now during Covid era we got students even from other continents. [chuckles] We are now slowly and painfully trying to put people back in in-person, because what do with those great students from elsewhere? And instructors, we got instructors that we would not have had otherwise.

BH: Has this... I mean you must have grander plans for this. You've always been doing this in California, have other ones started popping up?

ZS: Oh yes. So over the years many math circles have started around US, some of in Canada, all over in the world actually. Some of them were inspired by the Berkeley Math Circle. MSRI played a major role in supporting new circles and they still play such a role with grants, with support, and they organized conferences. In fact, the International Congress of Mathematics in St. Petersburg coming up will have a satellite conference called Math Circles Around the World. And so, I will surely be there.

BH: Does the fact that you've been creating these math circles, should that make me think, you know, this is fantastic, it's a lovely cherry on top or is this a sign of some kind of deficiency in the actual education system, that this kind of supplementary help is needed?

ZS: The answer is no and yes. No, because you had math circles in Bulgaria before. So that's your counter example, it wasn't a deficiency in the school system that drove students there to the math circles. So I've been asked this question many time, so what's the difference between math circles here and math circles back in Bulgaria from those times. And I would phrase it like this, it's not exact but approximately correct. Students in Bulgaria wanted to go to the math circle because they liked mathematics in school so much they wanted more. Something beyond. Many students in US come to the math

circles because they don't like [chuckles] the math in school and they want to see something else.

BH: They want different not more.

ZS: Different, not more of it. Of course there're exceptions and we have been working with teachers from great schools that definitely do a wonderful job but by and large the kids that come to the math circle here don't get what they want in math in school.

BH: What is that? How is the content in a math circle different from the content in their curriculum at school?

ZS: What they see at the math circle, they will likely never see in school, because the topic that we teach are not just beyond what they study there, they're just very different. Of course they will apply some of the knowledge that they've seen in school but you would not expect them to be doing combinatorial problems or number theory problems, geometry, and we're not talking here about calculus. A lot of parents come very confused to the math circles thinking that they advanced group is doing calculus. We are... very kind of... firm about this to tell them that calculus may not even appear in whole year of math circle. It doesn't have to appear, it's at any rate not the top of the pyramid. Calculus is just the base for real analysis and it's one of many different topics that students will see in the math circle.

BH: The students who come and do math circle... what's your hope for them? What do you hope that they will get from it? That they wouldn't have got otherwise? Are you hoping they will all become mathematicians or they'll get higher grades in their exams? Like... what's... what influence do you hope to have on them?

ZS: I would say... no to the higher grades on their exams. Not that they're not gonna get that but this is a total overkill. [laughs]

BH: Right.

ZS: You don't [laughs] you for example you're taking an elementary course in music in middle school and in order to learn how the notes work you go and play the piano for ten years. Well, that's a total overkill. Right?

BH: Yeah.

ZS: And after a certain point you cannot push kids to stay in the math circle unless they want to. This is just like playing the piano. After a certain point it's pointless to push someone to practice for five hours a day that they would want to do it or else, you know, let them free. So the students come to the math circle wanting to see more math.

They in fact get exposed to some other topics too. Occasionally some biology, some chemistry, computer science, of course all related in math. What comes out of that is very different when they graduate from the math circle. A lot of them continue to use mathematics throughout their lives. I can give you an example of Gabriel Carroll who was the very first year when we started the math circle. He was for several years at the math circle. But he was also on the US team at the International Math Olympiads, he got gold medals, he got a perfect score, he was also a brilliant pianist and what did he do? From what I remember he got a math major I think at Harvard, that's right, and then after that he went for a year to teach English as a foreign language in a province in China. You know, this superstar said I want to contribute somehow to the world. And upon coming back he applied to a PhD program in economics at MIT, not in mathematics, but when they called me from the admission committee as his reference to tell them about him, the only thing they asked me about Gabriel was his math background. They said, is he exceptional and my answer was, well, you get one person like this in a hundred years, except that in the math circle we have several every year [laughs].

BH: [laughs]

ZS: So he's right now a professor of economics in Canada. So you don't have to become a mathematician but what he experienced through math olympiads and mathematics definitely helped.

[gentle chimes]

BH: What's come of your mathematical career? Like, have you abandoned research? Like are you just full-time now doing things like math circle and nurturing future mathematicians? I kind of don't know what happened to you.

ZS: I have written several papers, research papers, in different areas, so algebraic geometry, but also combinatorics, over the years. So I went back in some way to my original research that I did as an underground but implementing the wisdom that I gathered from algebraic geometry. Along the way I started publishing books in math circles. The Decade of the Berkeley Math Circle volume one, was the founding book of a long series of MSRI and the American Math Society. It's called the Mathematical Circles Library. So they're about twenty-five books up to now. And we have two volumes on the Berkeley Math Circles. Those volumes are used, by the way, in university courses. That's how advanced this material is. So not just the math circles. I am translating, adapting, and co-authoring books for middle and high school students, textbooks. They are originally written in Bulgarian by Professor Paskalev and his wife but they had to be adapted to the US reality and so I have been doing that and putting a twist, a spin, so a

lot of things from the math circles end up there. Some stuff that I have taught at UC Berkeley courses...

BH: Okay.

ZS: ...end up in those textbooks. So to answer your question shortly, I'm now in a different position called teaching professor at UC Berkeley, so for many years I was on a regular research slash teaching position elsewhere but now I'm at UC Berkeley so yes, now most of my emphasis is delegated to most of efforts to teaching and to math circle and distributing this knowledge to thousands of kids actually every year.

BH: In the years that I've known you, I've gathered an impression and I've gathered again today that you think the Bulgarian school education system is better than the American one.

ZS: Does it show so obviously?

BH: [laughs]

ZS: It does. [chuckles]

BH: What's the key... I mean I know this is a huge question with a million answers but what's the kernel of it? What's the seed of the difference? What's the difference that you think that is fundamental that could improve American education, education everywhere?

ZS: Yeah this question are very politically charged.

BH: Mhm.

ZS: So I am treading here [chuckles] very carefully how to answer this. Um... the education that I know from Bulgaria is from the Communist times, when I came to US three months after that the Communist regime fell apart in Bulgaria, so I'm used only to the... Communist type of education and it was not perfect. I had to study history of Bulgarian Communist Party for which I didn't care [laughs] but the rest was fantastic and it was fantastic in my English language school. It was not fantastic absolutely everywhere but there was some sort of uniformity, some minimum that was quite high compared to what I see here in the US. The education in Bulgaria has changed for the twenty or so years dramatically, and from what I hear it has become closer to the American one.

BH: And what's the problem with that? What did that old system have that is lacking? Was it just harder? Was it throwing the kids in the deep end more or was it way of

teaching or...

ZS: It was... if I want one word to say it was systematic. It was building upon itself from the previous years. So if you have the same math teacher throughout let's say fourth through seventh grade, that math teacher knows the kids inside-out, knows their strengths, there is no repetition the following, there are no endless two month reviews and testing and retesting. They start immediately with the new material and they'll build upon, on solid foundation they can do this. And the same thing happened in high school, you had the same teacher for all four years there unless something drastic happened. So this kind of continuity of teachers was essential. In US people very afraid, parents are very afraid, and with good reason, that if they get the same teacher for several years and that teacher turns out to be bad then their kids are going to suffer and so you have this turn over in teachers from year to year, this kind of slowing down or lack of system, again I cannot crit... I am not in the position to criticize anyone here because I actually have worked with the cream of the crop of the teachers so there are numerous exceptions to this, don't get me wrong, but by and large teachers are overwhelmed with other things that they have to do in school, bureaucratic, administrative and different states require different things and very often a very low level in mathematics. And so you end up with teachers who are doing mathematics that... mathematical education that they may not themselves truly believe and only the toughest, the most creative ones get out of this and I... we have happened to have some great teachers for my kids so I cannot complain about that. So there's some pros and cons in both systems, I cannot quite see how to institute such a rigorous systematic system in the United States where different states cannot agree on some common standards. You have the Common Core standards, that is true, but how far does it reach?

BH: There's one more question I wanna ask you about. I wanna ask you about that teacher that made you stand at the blackboard for all that time. What ever happened to her? Did you look her up? Does she know what happened to you?

ZS: Oh she knows. She... I met her... later. I've been to Bulgaria not so many times since I came to US but I did meet her and she had only one comment for me. I knew it Zvezda [chuckles] that you would do it. And... that moment when I go back to fifth grade, she literally gave me a second chance but she gave it in such a way made me actually do the problem. Not just to give up and skip, knowing I had to do it.

BH: Did you learn from that? Do you use that technique?

ZS: No. No... I don't think my students are as tough as I was. [laughs] But I do tell my students something that Joe Harris my graduate... advisor told me. So he said, Zvezda,

we learn best from our own mistakes. And so I tell students the more mistakes you make before the final, probably you will be better [laughs] on the final [laughs] so it is time to do them right now in class and we'll correct them.

[gentle chimes]

ZS: I have to say that during this last year and a half of Covid, online, period, videos have become a major source, a learning source for not just students, for everyone and as we know the technology changed or its use has rather changed. So I see before I appreciated the Numberphile videos but now I'm thinking gosh, I'm using them in my classes. I did an introduction to proofs class at Berkeley last Fall and this Fall it is continued by one of my students. It's an actual course for undergrads and there when I was advertising I put all of my Numberphile videos and I said we're going to study all of this. [laughs] And that was very exciting for the students.

BH: That's what I like to hear. [laughs] We'll have to keep making more.

ZS: Well thank you, Brady.

BH: Alright.

ZS: I never expected that I would come to use and [gentle piano music fades in] actually lean on videos as much as now. [music fades up]

[music continues]

BH: Well that's all for today, but if you'd like to see Zvezda's videos on Numberphile, there will of course be a link in the notes for this episode. [music continues] Our thanks again to G-Research who sponsored today's show and the Mathematical Sciences Research Institute for supporting Numberphile. I'm Brady Haran and we'll be back soon with another podcast.

[music fades and cuts out]