
“I plan to be a great mathematician”: An NFL Offensive Lineman Shows He’s One of Us

Stephen D. Miller



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Mathematics folklore includes figures who made surprising contributions despite working a “day job” doing something else. Yet rarely has that line of work been as unexpected as that of John Urschel, guard/center for the Baltimore Ravens of the National Football League (NFL). Last season Urschel started two playoff games for the Ravens while simultaneously completing a paper on graph eigenfunctions (Urschel, Xu,

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Hu, and Zikatanov, 2015). He enters his second season not just as an interior lineman and kickoff return blocker but also as an MIT applied mathematics graduate student.

It’s not surprising that Urschel, as a 23-year-old rookie last year, received such widespread attention for his focus on and passion for uncommon outside interests. He’s clearly an exception among football players, though not the only one: half a century earlier, Frank Ryan quarterbacked the Cleveland Browns to an NFL title while writing a PhD thesis on complex analysis. During his graduate school/NFL days, Ryan circulated among the mathematics community during his off-seasons, even playing touch football with fellow young mathematicians such as future Wolf Prize winner Dennis Sullivan. Ryan’s Cleveland

Browns moved to Baltimore in 1996 and were renamed the Baltimore Ravens.

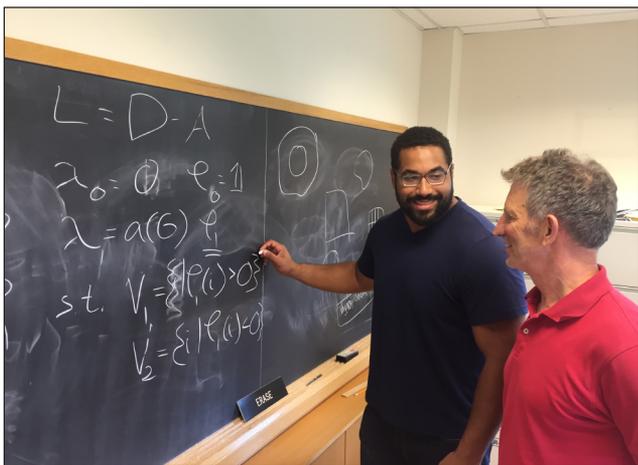
Like Ryan, the 6'3", 315-pound Urschel stands as an exception among mathematicians. Ever since his college years playing for Joe Paterno and Bill O'Brien at Penn State, Urschel's days have been filled with workouts and practice. Despite his striking appearance in a room full of mathematicians, Urschel is considered small for his position in the NFL. He compensates for his size with his mental and physical quickness. Offensive linemen must make rapid decisions both before the ball is snapped and while reacting to the defense as a play develops. The center, a position Urschel learned this past off-season, has the additional responsibility of communicating decisions to his teammates before snapping the ball.

Urschel's entrance into research mathematics came as a sophomore at Penn State, when his calculus instructor, Vadim Kaloshin, noted his talent and gave him some outside readings on dynamical systems to take with him on football team trips. Urschel went on to write a research paper on "Instabilities in the Sun-Jupiter-asteroid three body problem" with Kaloshin's student Joseph Galante and to write the paper with the Urschel—Zikatanov Theorem featured in Sidebar 1.

I interviewed John Urschel during his visit to the Institute for Advanced Study in Princeton in July 2015. A few weeks later Urschel suffered a concussion, which resulted in a public discussion between him and his coach, John Harbaugh, about advanced mathematics and this common NFL injury. Urschel had earlier written "Why I Still Play Football" on a colleague's early retirement due to concussions. That essay also described Urschel's background and introduction to mathematics.

Featured on *ESPN* and in *Sports Illustrated*, Urschel has become a prominent spokesman for the research mathematics community. My interview with Urschel explores how he combines his two interests of football and mathematics.

Miller: *In football you play the ultimate teamwork position, offensive line. How does that compare to writing joint papers in math?*



Urschel (left) at the Institute for Advanced Study with Peter Sarnak (right).

Sidebar 1: The Urschel—Zikatanov Theorem

The Urschel—Zikatanov Theorem concerns a nice way to divide a weighted graph (Figure 1) in two as in Figure 2; see Sidebar 2 for Figures. The two parts are where a certain eigenfunction of the graph Laplacian is nonnegative or negative. The graph Laplacian is a discrete version of the continuous Laplacian, a kind of negative second derivative. For a function f on the integers, the discrete analog of the second derivative is given by $2f(0) - f(-1) - f(1)$. For a graph with edge weights $w(x, y)$, the Laplacian is given by

$$\Delta f(x) = \sum w(x, y) - \sum w(x, y) f(y).$$

Urschel—Zikatanov Theorem. *Let G be a finite connected undirected weighted graph without self-loops. For an eigenfunction f of the Laplacian of the smallest possible eigenvalue, the sets where f is nonnegative and negative are both connected.*

J. C. Urschel and L. T. Zikatanov, Spectral bisection of graphs and connectedness, *Linear Algebra Appl.* **449** (2014), 1–16. For more on spectral graph theory, see Daniel Spielman's "On Graphs, Vectors, and Matrices" in the January 2016 *Notices*.

Urschel: In a joint paper, as in football, it's not this person or that person—it's the results that they produce together; you need everyone to contribute.

Miller: *How do you spend your free time on a road trip?*

Urschel: I read mathematics. These days I've been reading the most recent advances and manuscripts in unsupervised learning. I did just reread Gelfand's variational calculus book, which proved to be of some use for me, and I was recently reading a book on vector quantization, though it turned out to be more applied than I was hoping. I've also brought books such as *Algebraic Graph Theory* by Godsil and Royle with me while travelling. I've read through Meyer, Trefethen and Bau, and frequently bring *Matrix Analysis* with me as a reference.

I'm at the stage where I'm reading more research papers than textbooks, especially in the areas of numerical PDEs and numerical linear algebra. In addition to keeping track of interesting things going on in those specialties, I'm constantly reading other areas of mathematics. I wish I had more time to read mathematics—football keeps me very busy and this limits the breadth of my mathematical knowledge a lot more than I would like it to. I would like to have a better knowledge of pure mathematics as well as a deeper knowledge of a lot of different areas of applied mathematics.

Miller: *Many mathematicians find it hard to avoid thinking about math, and many football fans are often consumed by the excitement of an upcoming big game. How do you shut off one part of your mind in order to focus on a second interest?*



Urschel: I think the difference is that if I'm thinking about math on the football field, this is going to get me killed. So that's just survival instinct. And when I'm doing math, it's all encompassing and I'm 100 percent in it, and there's really nothing else to think about when I'm doing math. I love mathematics, I love the elegance, I love the challenge, and so that's been natural for me.

Miller: You clearly have the ability to concentrate on things and to work very hard, e.g., practicing six hours a day. But math has a creative side. If you are creative as a football player, Coach Harbaugh probably won't be too happy with you.

Urschel: No, he wouldn't be. I'm extremely focused playing football, and this focus does carry over into math, in that I'm very competitive: mainly competitive with the problem, where it's me vs. the unknown. There is something to be said for creativity and innovation on the football field, though I don't think it carries over across the two subjects as much as competitiveness does.

Miller: Like mathematics arguments, a lot of NFL plays involve abstracting down to a problem that's already been solved. Do you get a similar feeling when you see a great strategy as you do when you see a great proof?

Urschel: The difference is that a great proof is an amazing accomplishment and feat, whereas a great play-strategy would be equivalent to a sketch of a proof. The execution of the actual thing that you imagine and practice, the actual play—that is the accomplishment. A play written up on the blackboard is just a sketch, which could go a variety of ways when attempted rigorously in practice.

Miller: How do you compare the stress level between football and mathematics?

Urschel: My stresses in math are all self-imposed, and these are good stresses: the desire to achieve, the desire to accomplish. My goal is to be a mathematician who people

Sidebar 2: The Spectral Partition

The spectral partition (Figures 1 and 2) reveals a striking nonrandom feature of the 2015 NFL schedule: one cluster of 16 teams (the NFC and AFC North and West divisions, including Urschel's own Baltimore Ravens) plays only 32 games against the complementary cluster of 16 teams. In contrast, the AFC and NFC conferences play 64 games against each other. Indeed, the smallest positive eigenvalue is only 4 for the 2015 schedule graph, whereas it is usually 6. Moreover, Urschel's Ravens are in the cluster which included more competitive teams in 2014: for example, all of the playoff Wild Card teams are in his cluster. This indicates that teams in the other cluster likely have an easier route to the playoffs in 2015 thanks to this graph-theoretic anomaly.

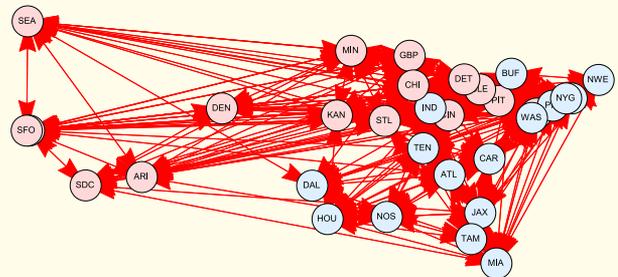


Figure 1. The 32 NFL teams connected by edges weighted by how many times they play each other during the regular 2015 season.

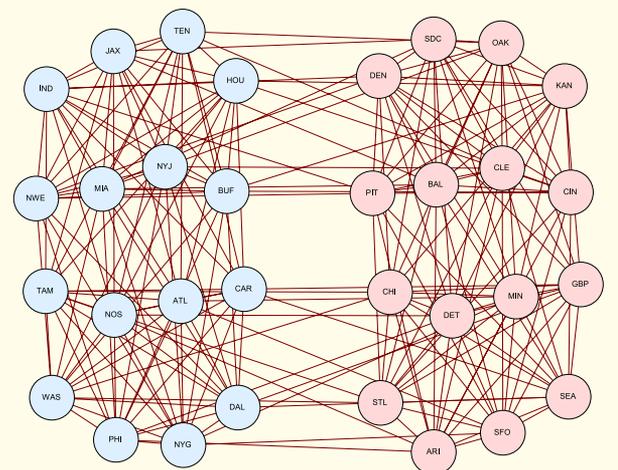


Figure 2. The Urschel—Zikanov Theorem separates the NFL teams of Figure 1 into two clusters, where a certain eigenfunction is nonnegative or negative. Strikingly, in 2015 these two clusters play an abnormally low number of games against each other.

look back on and say, “Yes, he did make good contributions. He helped push mathematics along.”

Miller: Thank you for taking the time to speak to the Notices, and best of luck to you as you start your PhD studies at MIT.

The math community is a community I respect so much. I deeply desire to be accepted into it, and accepted as a legitimate member.

and to be welcomed as one of your own.

Urschel: The math community is a community I respect so much. I deeply desire to be accepted into it, and accepted as a legitimate member. I’d like people to not just look at the headlines and say, “Oh, that NFL player majored in math.” I understand the mainstream media is very quick to name people “math wizards” and “math geniuses” even if all they are doing is dabbling into a couple of statistics. I’d like the community to give me a chance, to look at my work, and not judge me too quickly. I very much seek approval from the mathematics community



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