

ACTIVITY REPORT FOR CDC VLP PROGRAM

Volunteer: Tevian Dray
Department of Mathematics
Oregon State University
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Host: Institut de Mathématiques et de Sciences Physiques (IMSP)
Université de Abomey-Calavi
Porto-Novo, BÉNIN

Dates: 21 October 2018 – 11 November 2018

(To the best of my knowledge, no IMU representatives or IMU adhering organizations were involved in this project.)

Info: *Arrival:* 21 October 2018
Departure: 11 November 2018
Contact: Prof. Cyriaque Atindogbé
Location: IMSP, Porto-Novo, BÉNIN
Lecture Dates: 22 October 2018 – 9 October 2018
Course Title: Lorentzian Geometry and General Relativity
Class Meetings: 4 days/week; 4 hours/day
of Students: 16 students participated; 10 took the course for credit
Level: Master and Ph.D. students
Topics: (see attached list)
Syllabus: Used my own, based on courses previously taught.
(Was modified often and not available to students.)
Text: Used my own textbook. (Available to students as a PDF file.)
Assessment: 2 homework assignments (40%); final exam (60%).
Language: English, supplemented by French when necessary.
(French was the 2nd language of most students; English the 3rd.)
Public Lecture: IMSP-wide colloquium on active engagement in mathematics.
Housing: Hotel

LORENTZIAN GEOMETRY AND GENERAL RELATIVITY

Topics Covered:

- Hyperbola Geometry
- Hyperbolic Trigonometry
- Minkowski Geometry
- Special Relativity
- Differential Forms
- Hodge Duality
- Exterior Derivatives
- Connection 1-forms
- Curvature 2-forms
- Geodesics
- Killing Vectors
- Schwarzschild Geometry
- Black Holes
- Einstein's Equation
- Roberston–Walker Cosmologies
- Gravitational Waves
- Lightlike Submanifolds

Textbook:

Differential Forms and the Geometry of General Relativity,
Tevian Dray,
A K Peters/CRC Press, Boca Raton, FL, 2014.

ACHIEVEMENTS

Summary: *Successfully taught basics of Lorentzian geometry to mixed audience of Masters and PhD students of mathematics. Gave colloquium on active engagement in mathematics. Explored possible topics for future collaboration.*

I was invited on short notice to be an IMU Visiting Lecturer at the Institut de Mathématiques et de Sciences Physiques (IMSP) of the Université de Abomey-Calavi in Bénin. The IMSP is a Centre d'Excellence Africain en Sciences Mathématiques et Applications, sponsored by the World Bank. My visit took place from 21 October to 11 November 2018 – exactly 1 month after the initial invitation. While at the IMSP, I taught a graduate course in Lorentzian Geometry and General Relativity, meeting four hours per day, four days per week, for three weeks. I also discussed research topics with several faculty members and students at the IMSP. Finally, at the request of the Adjoint Director of the IMSP, who had noticed my work in science education, I gave an institute-wide colloquium (seminaire générale) on active engagement in mathematics.

With the strong encouragement of my hosts, I chose to teach my course primarily in English – the third language for most of the students, with French serving as the common language at the IMSP, whose students come from much of West and Central Africa. My French was quite good although rusty, as I had spent roughly a year living in France, but nearly 40 years ago. Students could use either language during discussions, and I attempted to translate things like announcements and assignments.

Not surprisingly, both the language and the mathematical abilities of the 16 students were mixed; there were Masters students fairly early in their career and Ph.D. students literally weeks from their degrees. My geometric approach to relativity was a good match for both groups, emphasizing elementary examples to illustrate key concepts, but immediately applying them in the less familiar context of Lorentzian, rather than Riemannian, geometry. I was able to use my own textbook, which was made available to students as a prepublication PDF document.

The class was scheduled in a single, 4-hour block, four days per week, and ran for three weeks. This scheduling precluded a traditional lecture format, so I interspersed both individual and group calculations throughout the period. That format worked reasonably well, although language and cultural differences were quite noticeable. The course concluded with a traditional, proctored, in-class exam, which I was able to grade before leaving Bénin.

My colloquium, entitled *Using Active Engagement to Teach Mathematics*, was adapted from talks developed (and presented) jointly with my wife, physicist and physics education researcher Corinne Manogue, in which we model various classroom techniques, then discuss their advantages and disadvantages. Again, I spoke in English, although I translated key parts of my slides (such as instructions to the audience) into French. This talk was very well received, by a mixed audience of both students and faculty.

Finally, I had short conversations with one or two faculty members about both my research and theirs, with a view toward establishing common ground for future collaboration; I also had similar conversations with a couple of advanced students, regarding papers they were reading at the request of their supervisor. In all cases, some progress was made, although little actual collaboration took place.

FUTURE PLANS

Both my host, Prof. Atindogbé, and my local mentor, Dr. Franck Houenou, are differential geometers, as I am; in fact, I was invited to visit in large part because Prof. Atindogbé had done some work on lightlike submanifolds, a topic on which I had also published a few papers. So we naturally wanted to explore the possibility of further collaboration. Unfortunately, there were not many opportunities to do so. For a variety of reasons, Prof. Atindogbé was unable to spend much time at the IMSP during my visit, although we met twice in his home city of Calavi, more than an hour away. Dr. Houenou studies symplectic manifolds, a topic I know much less about; although we did manage to find the time to discuss his work, it seems unlikely that we will continue to do so.

Nonetheless, there are several promising possibilities for future interaction. First of all, while trying (unsuccessfully) to draft lecture notes on lightlike submanifolds for my course, I realized that what I was attempting to outline might make a good paper. I hope to pursue this project as time permits, and plan to consult both Prof. Atindogbé and Dr. Houenou along the way.

Second, Dr. Houenou expressed considerable interest in my more recent research on the octonions – and the IMSP indicated that they would be delighted to host me again, and might even be able to provide the necessary travel support. So a future course on the octonions might be feasible, and might in turn lead to further collaboration and/or student projects. The IMSP also indicated strong interest in inviting my wife as well, an internationally noted expert in (physics) curriculum development and education research.

Last but not least is the relationship I developed with the two or three best students. Pure research support for mathematics students is rare in the US; most students are supported through teaching, requiring high-quality English. Although finding suitable positions will be a huge challenge, I am now in a position to write letters on behalf of some students, providing a Western assessment of their abilities.