

Curriculum Vitae

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EDUCATION

Ph.D.: University of Illinois at Urbana-Champaign, Physics, May 2005
Thesis topic: *Quantum Mechanical/Molecular Mechanical
Studies of F_1 -ATPase and a Plant Photoreceptor*
Thesis advisor: Professor Klaus Schulten

Diploma: University of Regensburg, Physics, September 2000

PROFESSIONAL EMPLOYMENT

May 2005 – present: Postdoctoral research associate in the Theoretical and Computational Biophysics Group, Beckman Institute, University of Illinois at Urbana-Champaign.

October 2005 – present: Developer for Gentoo Foundation, Inc., scientific and cluster applications.

January 2001 – May 2005: Graduate research assistant in the Theoretical and Computational Biophysics Group, Beckman Institute, University of Illinois at Urbana-Champaign. Supervisor: Professor Klaus Schulten.

Spring 2000: Teaching assistant, Biophysics Department, University of Regensburg, Germany. Supervised a physics practical for medical students.

Fall 1996/Spring 1999: Teaching assistant, Math Department, University of Regensburg, Germany. Duties involved instructing students and grading homework assignments for an introductory math class for life scientists.

ACADEMIC HONORS

University of Illinois at Urbana-Champaign (2001-present)
Renato Bobone Award, Physics Department (2003)

University of Regensburg, Germany (1994-2000)
DAAD Scholarship (1997)

RESEARCH ACCOMPLISHMENTS

Chemo-Mechanical Coupling in F₁-ATPase with Shigehiko Hayashi and Klaus Schulten. We used combined quantum mechanical/molecular mechanical (QM/MM) and molecular dynamics (MD) simulations to study the ATP hydrolysis reaction in the catalytic binding pockets of F₁-ATPase and its coupling to mechanical rotation of the central stalk. Our simulations revealed a novel proton relay mechanism as the energetically most favorable pathway for efficient hydrolysis. Furthermore, we were able to identify a specific arginine residue as essential for synchronizing the catalytic sites in F₁ to achieve the cooperativity observed during its operation. Finally, we were able to show that the ATP hydrolysis reaction itself has an equilibrium constant of $K \sim 1$ and does not, therefore, constitute the force generating step during F₁ operation.

Photoexcitation in LOV Domains with Peter Freddolino and Klaus Schulten. We investigated the photocycle of a light, oxygen, and voltage (LOV) sensitive domain in a blue-light receptor found in the algae *C. reinhardtii* using QM/MM and MD simulations. For the first time, the ground and the flavin-cysteinyl adduct state as well as several triplet intermediate states of a complete LOV domain could be characterized at electronic level detail. In addition, our simulations allowed us to unambiguously classify the adduct formation pathway as being of the radical pair type.

Development of QM/MM code with Shigehiko Hayashi and Klaus Schulten. We have developed an efficient and powerful QM/MM method based on the quantum chemistry package GAMESS using the AMBER force field for the classically modeled region of the biomolecular system. Our code runs efficiently on up to 32 processors and is capable of performing Hartree-Fock as well as density functional based calculations.

Coarse-Graining Methods for Biomolecules with Rob Phillips and Klaus Schulten. We developed and investigated a coarse-graining scheme for proteins that builds upon methods used in materials science. Our approach employs a residue-centric description to reduce the system's degrees of freedom. A residue based local basis system can then be used to recover the all-atom description of the protein at any time from the coarse grained model.

CURRENT RESEARCH

Protein Dynamics of LOV Domains with Peter Freddolino and Klaus Schulten. We are currently investigating how photon induced flavin-cysteinyl adduct formation in LOV domains can induce signaling events to a neighboring kinase domain in light of only minor structural differences observed in available crystal structures. This project involved the parameterization of the chromophore flavin mono-nucleotide using quantum chemistry calculations.

DNA translocation in PcrA helicase with Klaus Schulten. Complementing our studies of F₁-ATPase, we are currently investigating the chemo-mechanical coupling of ATP hydrolysis to DNA translocation in PcrA helicase. Lacking the catalytic site cooperativity of F₁-ATPase, PcrA helicase provides an ideal test system to study the coupling of a chemical reaction to mechanical force generation. Our calculations reveal two distinct pathways for ATP hydrolysis in the PcrA catalytic site which both proceed via the proton relay mechanism proposed earlier in our work on F₁-ATPase.

Photoexcitation dynamics of PYP with Klaus Schulten and Keith Moffat. We are using equilibrium and steered molecular dynamics simulations to investigate the events immediately following the light induced isomerization of the chromophore cinnamic-acid and their coupling to a potential signaling state of the protein. The computational modeling of the experimentally observed very short hydrogen bonds between the chromophore and the protein required a careful parameterization of the chromophore as well as of the neighboring residues using quantum chemistry calculations.

PUBLICATIONS

M. Dittrich, and Klaus Schulten, “Zooming in on ATP hydrolysis in F₁,” *Journal of Bioenergetics and Biomembranes* **37**, 441 (2005).

M. Dittrich, P. Freddolino, and K. Schulten, “When Light falls in LOV: A QM/MM Study of Photoexcitation in Phot-LOV1 of *C. Reinhardtii*,” *J. Phys. Chem. B* **109**, 13006 (2005)

M. Dittrich, S. Hayashi, and K. Schulten, “ATP hydrolysis in the β_{TP} and β_{DP} catalytic sites of F₁-ATPase,” *Biophysical Journal* **87**, 2954 (2004)

M. Dittrich, S. Hayashi, and K. Schulten, “On the mechanism of ATP hydrolysis in F₁-ATPase,” *Biophysical Journal* **85**, 2253 (2003)

R. Phillips, M. Dittrich, and K. Schulten, “Quasicontinuum representations of atomic-scale mechanics: From proteins to dislocations,” *Ann. Rev. Mat. Res.* **32**, 219 (2002)

TALKS

“Insights into the mechanism of molecular motors,” Seminar, Stiles Laboratory, Pittsburgh Supercomputing Center, Pittsburgh, PA, March 30, 2006.

“Quantum mechanical/molecular mechanical simulations of biomolecular systems,” Seminar, Sandia National Laboratory, Albuquerque, NM, March 2, 2006.

“Quantum mechanical/molecular mechanical simulations of biomolecular systems,” Seminar, A. Sali Laboratory, UCSF, San Francisco, CA, December 14, 2005.

“Quantum mechanical/molecular mechanical simulations of biomolecular systems,” Seminar, D. Baker Laboratory, Univ. of Washington, Seattle, WA, October 25, 2005.

“When light falls in LOV: A computational study of a plant photoreceptor,” Biophysics and Computational Biology Summer Symposium, Illinois Biophysics Society, Urbana, IL, July 26, 2005.

“Quantum mechanical/molecular mechanical simulations of biomolecular systems,” International Workshop on Classical and Quantum Dynamical Simulations in Chemical and Biological Physics, Max Planck Institut für die Physik Komplexer Systeme, Dresden, Germany, June 9, 2005.

“Computational Study of the Chemomechanical Coupling and ATP Hydrolysis in F_1 -ATPase,” Biophysical Society Annual Meeting, Long Beach, CA, February 16, 2005.

“Insights into the molecular mechanism of ATP synthase,” Gordon Conference on Molecular and Cellular Bioenergetics, Andover, NH, June 24, 2004.

POSTER PRESENTATIONS

“A Computational Study of ATP Hydrolysis and Force Generation in PcrA Helicase,” Biophysical Society Annual Meeting, Salt Lake City, UT, February 2006.

“QM/MM study of ATP hydrolysis in F_1 -ATPase,” Biophysical Society Annual Meeting, Baltimore, MD, February 2004.

“ATP hydrolysis in F_1 -ATPase: A combined ab initio QM/MM study,” Biophysical Society Annual Meeting, San Antonio, TX, February 2003.

PERSONAL REFERENCES

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