# Seminar of SFB 910



## Deepak Gupta

Simon Fraser University, British Columbia, Canada


# Minimum-dissipation protocol for $F_1$-ATPase molecular motor

**The event is part of the group seminar AG Klapp at TU Berlin and will take place via Zoom. For information on how to access the event, please contact: henning.reinken@itp.tu-berlin.de**

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**Wednesday, 30.03.2022 · 16:00h · via Zoom**

Technische Universität Berlin · Institut für Theoretische Physik · Hardenbergstraße 36 · 10623 Berlin

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# Minimum-dissipation protocol for $F_1$-ATPase molecular motor

**Deepak Gupta**[1], Steven J. Large[1], Shoichi Toyabe[2], and David A. Sivak[1]

[1]Department of Physics, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada

[2]Department of Applied Physics, Tohoku University, Aoba 6-6-05, Sendai, 980-8579, Japan

A biomolecular motor composed of protein complexes exchanges energy, matter, and information with its surrounding. Despite being in contact with a fluctuating environment, it performs (on average) a directed motion, in accordance with the second law, by transducing chemical energy stored in the surrounding environment[1]. Among several biomolecular motors, $F_OF_1$-ATPsynthase has gained much attention due to its high efficiency[2]. It produces ~95% of the cellular ATP (adenosine triphosphate) from ADP (adenosine diphosphate) and $P_i$ (inorganic phosphate). The membrane-embedded $F_O$-unit utilizes energy from proton flux to rotate $F_1$-unit's γ-crankshaft and synthesizes ATP molecules. Since γ-crankshaft rotates as fast as ~350 revolutions per second, it remains a puzzle how $F_OF_1$ transduces energy with great efficiency. One possible way to investigate this is to uncover the functional principle of that particular unit where ATP is synthesized, i.e., $F_1$-ATPase. To this end, we focus on an isolated $F_1$-ATPase, which can also be controlled in an experimental setup[3]. We aim to design a control protocol (mimicking $F_O$ operation) by which the $F_1$ unit's γ-crankshaft can be rotated to synthesize ATP at low dissipation. We follow a theoretical method valid near-equilibrium[4] to construct a non-trivial designed protocol. Then, we rotate the crankshaft with this designed protocol to compute dissipation. Our analysis reveals that the designed protocol dissipates a less amount of energy in comparison to a constant velocity protocol for a wide range of protocol durations[5].

1 Mugnai, M. L., Hyeon, C., Hinczewski, M. & Thirumalai, D. Theoretical perspectives on biological machines. Rev. Mod. Phys. 92, 025001 (2020).

2 Soga, N., Kimura, K., Kinosita, K., Yoshida, M. & Suzuki, T. Perfect chemomechanical coupling of $F_OF_1$-ATPsynthase 114, 4960–4965 (2017).

3 Toyabe, S. et al. Nonequilibrium energetics of a single $F_1$-ATPase molecule. Phys. Rev. Lett. 104, 198103 (2010).

4 Sivak, D. A. & Crooks, G. E. Thermodynamic metrics and optimal paths. Phys. Rev. Lett. 108, 190602 (2012).

5 Gupta, D. et al. Minimum-dissipation protocol for $F_1$-ATPase molecular motor. Manuscript in preparation.