Софийски университет „Св. Климент Охридски“
Физически факултет
Катедра „Атомна физика“

Създаване на библиотека за неявно описание на воден разтворител за молекулна динамика

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Атестационен семинар
26.06.2014г.

AGBNP2

- Неявно описание на взаимодействието на вещества с воден разтворител
- Алгоритъм за оценка/пресмятане на радиусите на Борн и повърхнините на атомите, който „не зависи“ от параметри, а от конформацията на молекулата
- Неполярен член в свободна енергия на разтворимост
- Приложим към широк диапазон от молекули и функционални групи

[1] E. Gallicchio and R.M. Levy, *AGBNP: An Analytic Implicit Solvent Model*, J. Comput. Chem. 25(4) 479-499 (2004).

[2] E. Gallicchio, K. Paris and R.M. Levy, *The AGBNP2 Implicit Solvation Model*, J. Chem. Theory Comput. 5(9), 2544–2564 (2009).

Енергия на разтворимост

$$\Delta G_h = \Delta G_{elec} + \Delta G_{cav} + \Delta G_{vdW} + \Delta G_{hb}$$

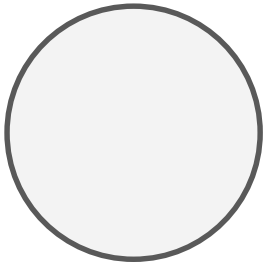
$$\Delta G_{elec} \cong \Delta G_{GB} = u_\varepsilon \sum_{ij} \frac{q_i q_j}{f_{ij}} = u_\varepsilon \sum_i \frac{q_i^2}{B_i} + 2u_\varepsilon \sum_{i<j} \frac{q_i q_j}{f_{ij}}$$

$$= u_\varepsilon \sum_i \frac{q_i^2}{B_i} + \sum_{i<j} \frac{q_i q_j}{\sqrt{r_{ij}^2 + B_i B_j \exp\left(-r_{ij}^2 / 4 B_i B_j\right)}}$$

$$\Delta G_{cav} = \sum_i \gamma_i A_i = \sum_i \gamma_i \left(\frac{\partial V}{\partial R_i} \right)$$

$$\Delta G_{vdW} = \sum_i \alpha_i \frac{16 \pi \rho_w \varepsilon_{iw} \sigma_{iw}^6}{3\left(B_i + R_w\right)^3} = \sum_i \alpha_i \frac{a_i}{\left(B_i + R_w\right)^3}$$

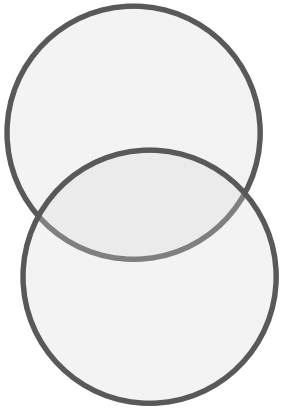
Модел за обема



$$\rho_i(\mathbf{r}) = p \exp\left[-c_i(\mathbf{r}-\mathbf{r}_i)^2\right]$$

$$p = \frac{4\pi}{3}\left(\frac{\kappa}{\pi}\right)^{3/2}; \qquad c_i = \frac{\kappa}{R_i^2}; \qquad \kappa = 2.227$$

Модел за обема



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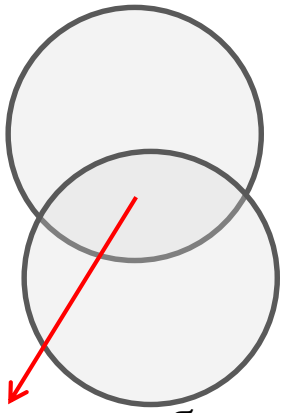

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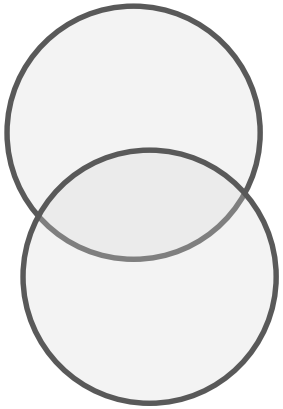

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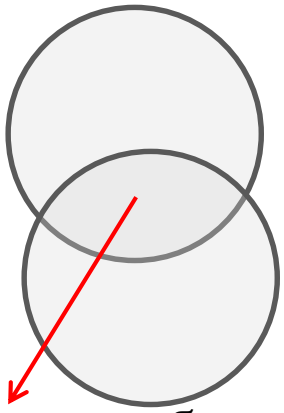

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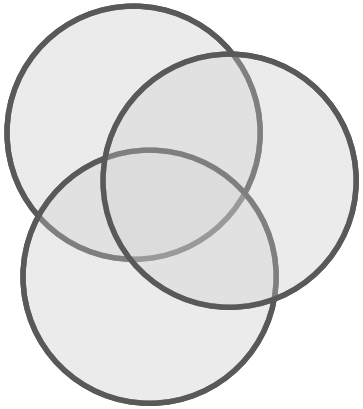

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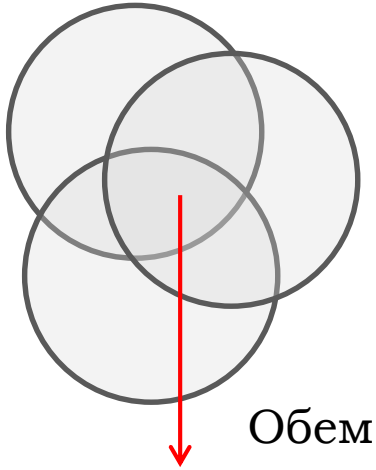

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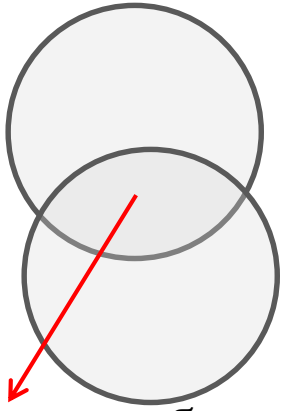

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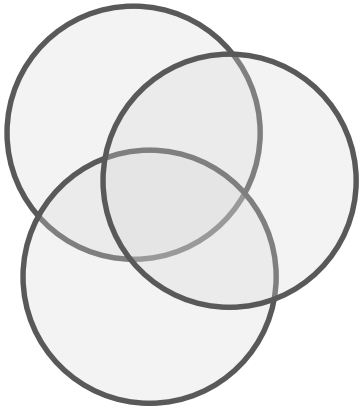

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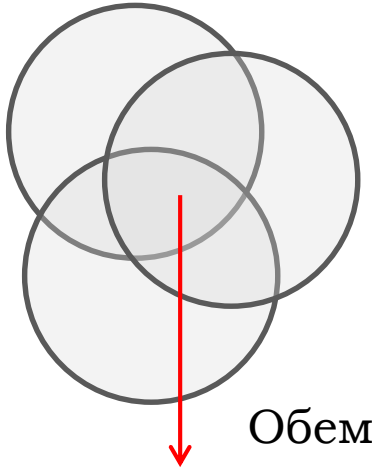

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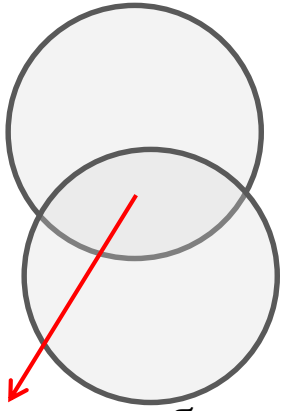

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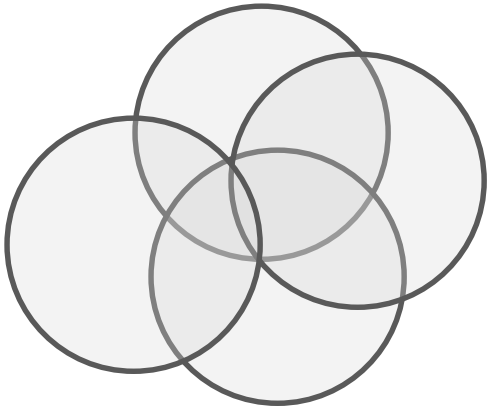

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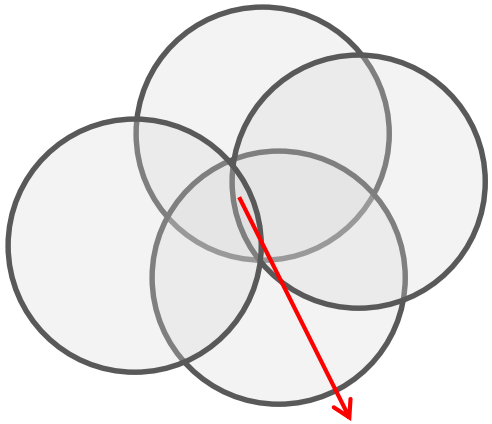

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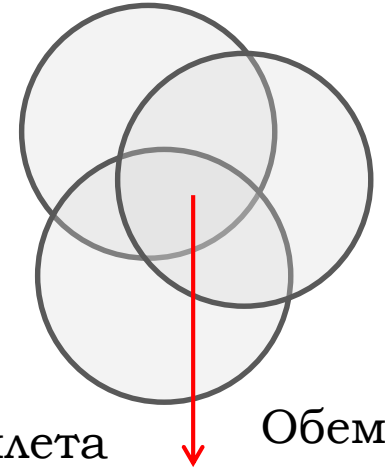

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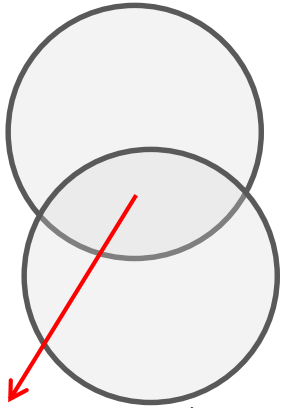

Обем на сечението на дублета

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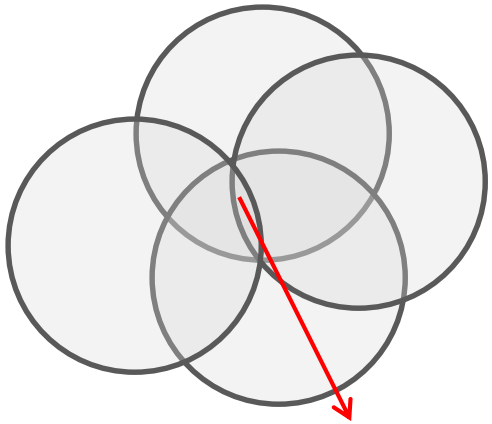

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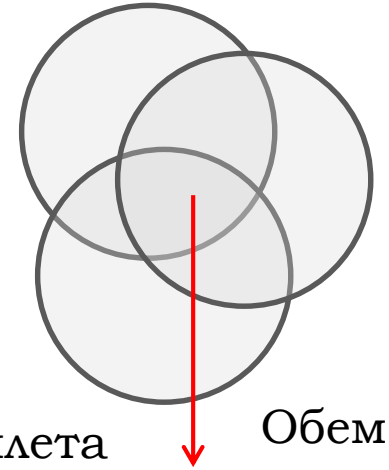

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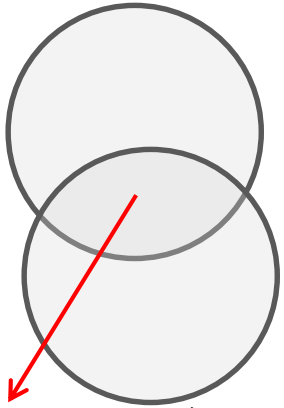


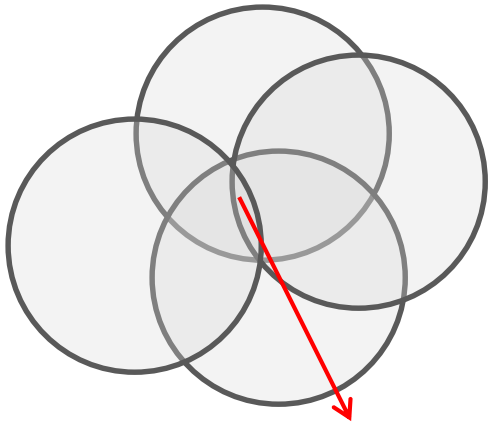
Обем на сечението на дублета

Обем на сечението на мултиплета

$$V_{12\ldots n}^{g} = p^{n} \exp\left(-K_{12\ldots n}\right)\left(\frac{\pi}{\sum_{i=1,\ldots,n} c_i}\right) \qquad p = \frac{4\pi}{3}\left(\frac{\kappa}{\pi}\right)^{3/2};$$

$$K_{12\ldots n} = \frac{1}{\sum_{i=1,\ldots,n} c_i} \sum_{i=n}^{n} \sum_{j=i+1}^{n} c_i c_j r_{ij}^{2} \qquad c_i = \frac{\kappa}{R_i^{2}}; \qquad \kappa = 2.227$$

Модел за обема



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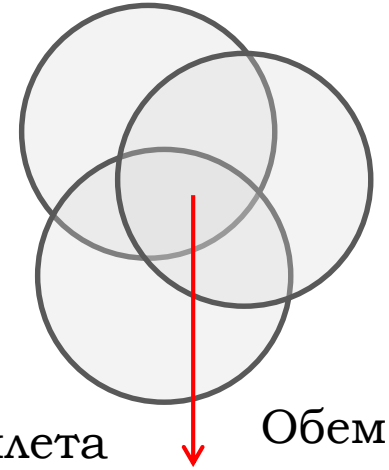
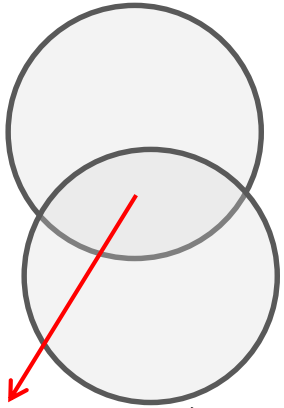


Обем на сечението на триплета

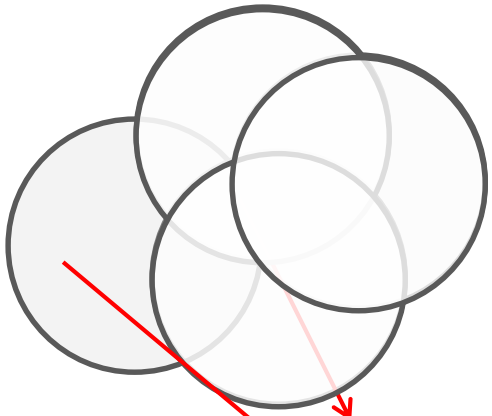


Обем на сечението на дублета

Обем на молекулата

$$V = \sum_{i} V_i - \sum_{i<j} V_{ij} + \sum_{i<j<k} V_{ijk} - \sum_{i<j<k<l} V_{ijkl} + \ldots$$

Модел за обема



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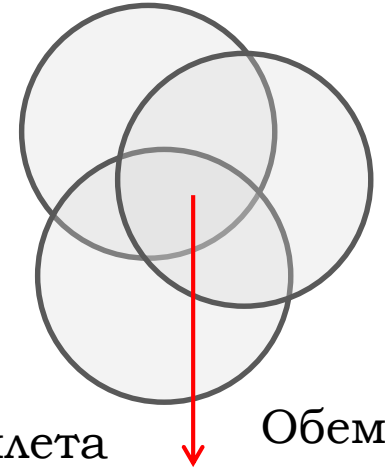

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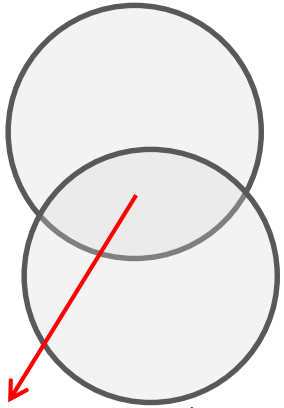

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$$V = \sum_{i} V_i - \sum_{i<j} V_{ij} + \sum_{i<j<k} V_{ijk} - \sum_{i<j<k<l} V_{ijkl} + \ldots$$

Собствен обем на атома

$$V_i' = V_i - \frac{1}{2}\sum_{i} V_{ij} + \frac{1}{3}\sum_{j<k} V_{ijk} - \frac{1}{4}\sum_{j<k<l} V_{ijkl} + \ldots$$

Радиус на Борн

$$\frac{1}{B_i} = \beta_i = \frac{1}{R_i} - \frac{1}{4\pi}\int_{\Omega_i} d^3\mathbf{r}\,\frac{1}{\left(\mathbf{r}-\mathbf{r}_i\right)^4} = \frac{1}{R_i} - \frac{1}{4\pi}\sum_{j\neq i} Q_{ji}$$

$$\frac{1}{B_i} = \frac{1}{R_i} - \frac{1}{4\pi}\sum_{j\neq i} s_{ji} Q_{ji} = \frac{1}{R_i} - \frac{1}{4\pi}\sum_{j\neq i}\left(\frac{V_j^{'} - d_j A_j + V_{ji}^{'}}{V_j}\right) Q_{ji}$$

$$V_i^{'} = V_i - \frac{1}{2}\sum_i V_{ij} + \frac{1}{3}\sum_{j<k} V_{ijk} - \frac{1}{4}\sum_{j<k<l} V_{ijkl} + \ldots$$

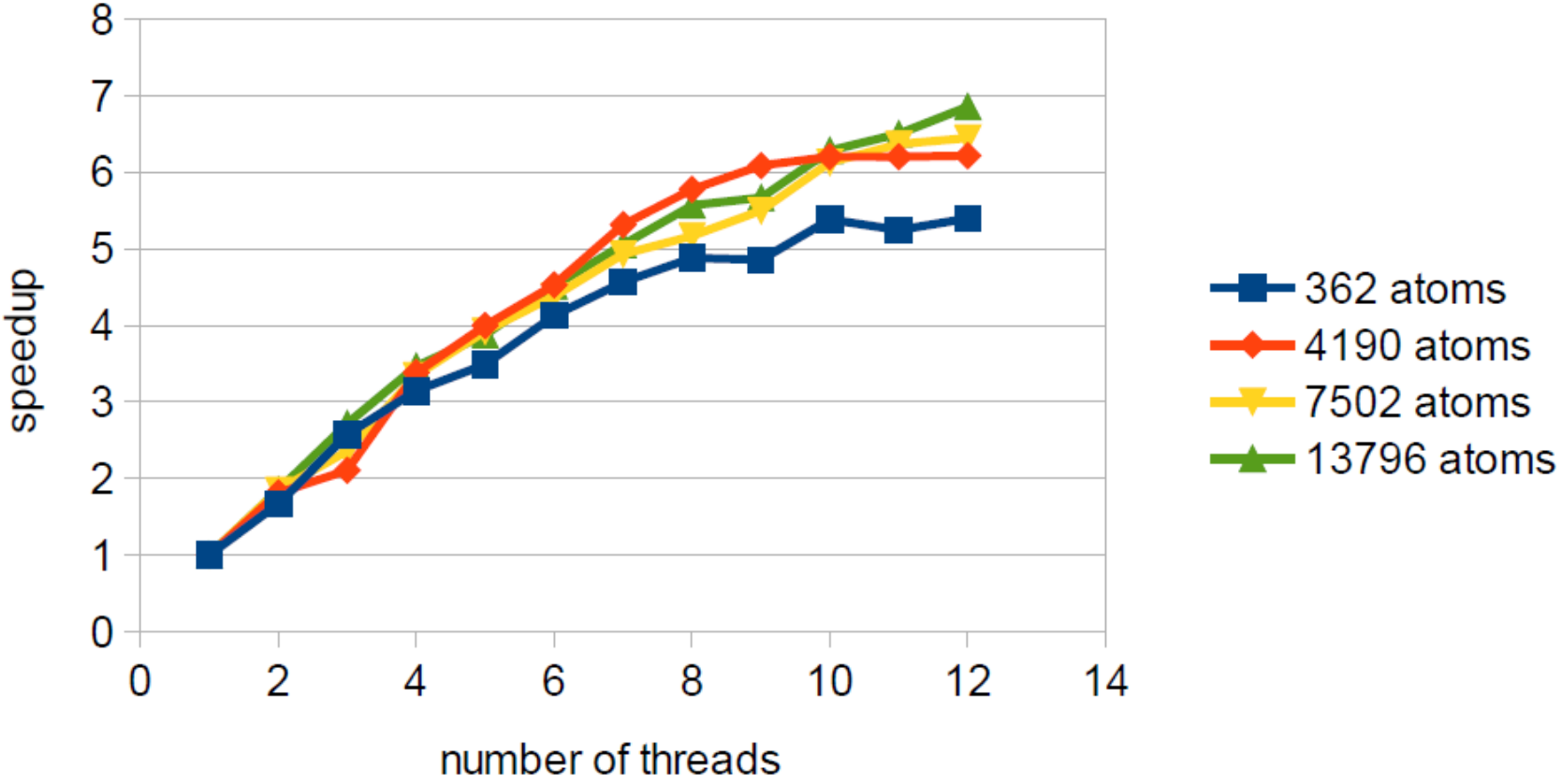
$$V_{ij}^{'} = V_{ji}^{'} = \frac{1}{2}V_{ij} - \frac{1}{3}\sum_k V_{ijk} + \frac{1}{4}\sum_{k<l} V_{ijkl} + \ldots$$

Структури от данни

- Атомни свойства
  - Индексите вървят по номера на атома
  - Споделена между нишките
  - Използва се в паралелни FOR цикли
- Мулти-плети
  - Индексите зависят от номера на нишката и от номера на мултиплета
  - Собствена за всяка нишка без преповтаряне на данни
  - Паралелни цикли по собствени данни

Последователност на програмата

Резултати
Fortan90 + OpenMP
Intel Xeon CPU E5649 with HT enabled



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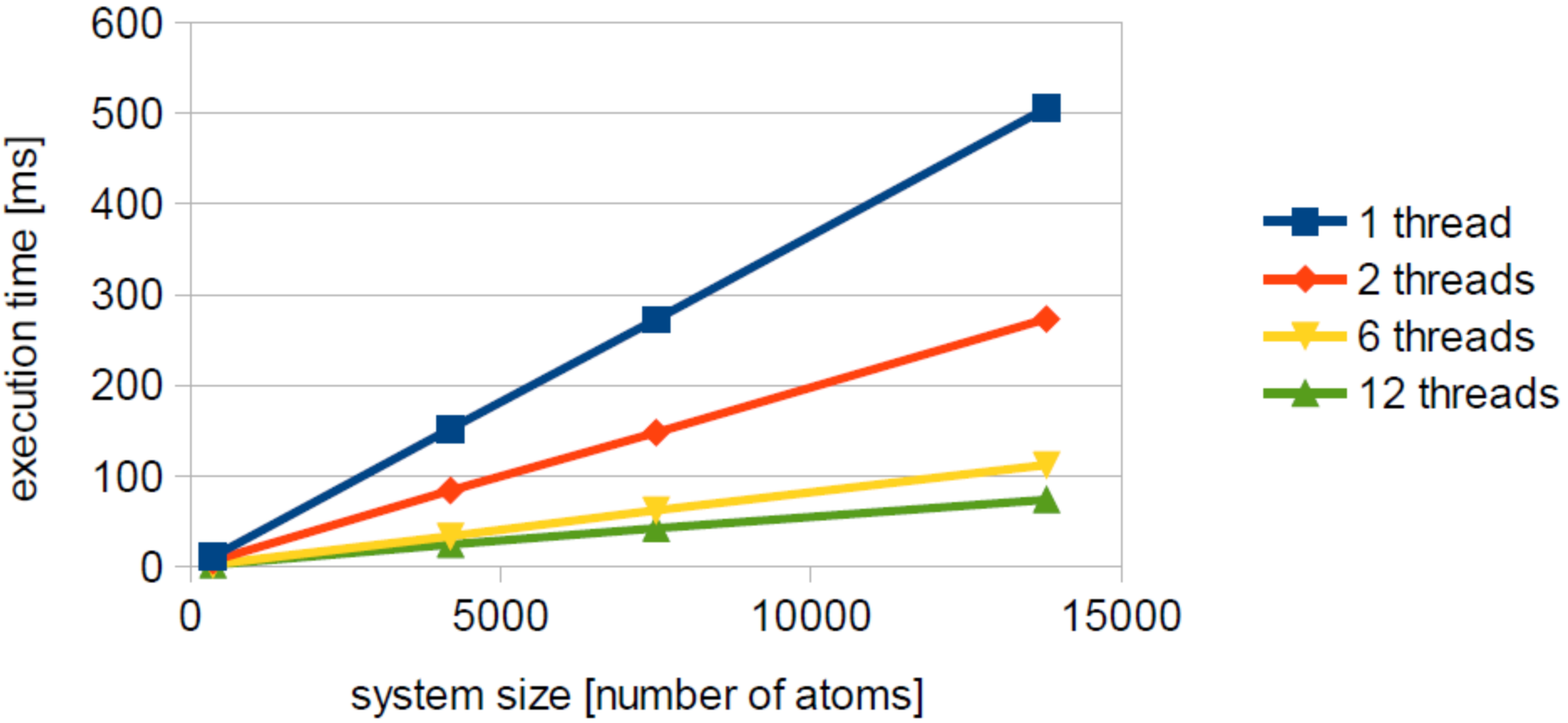
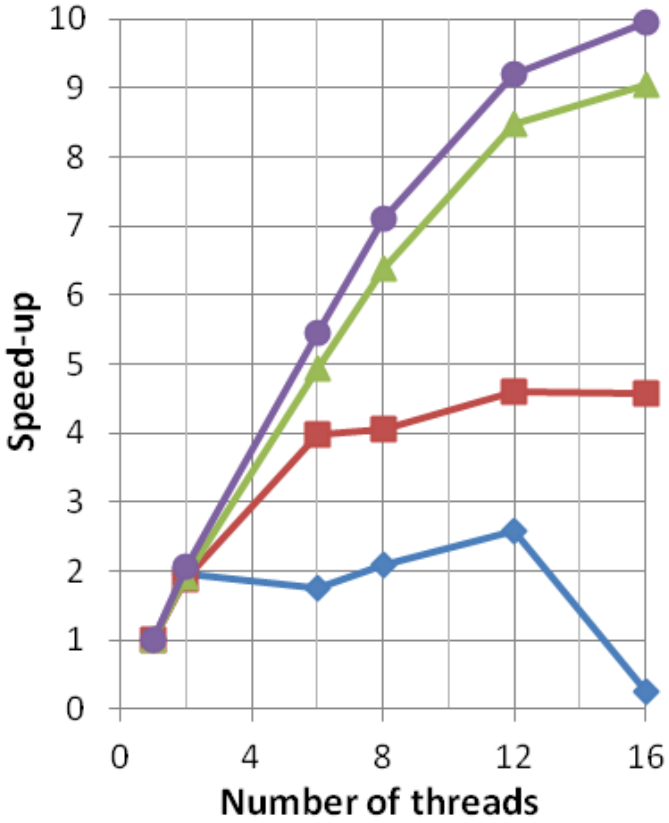
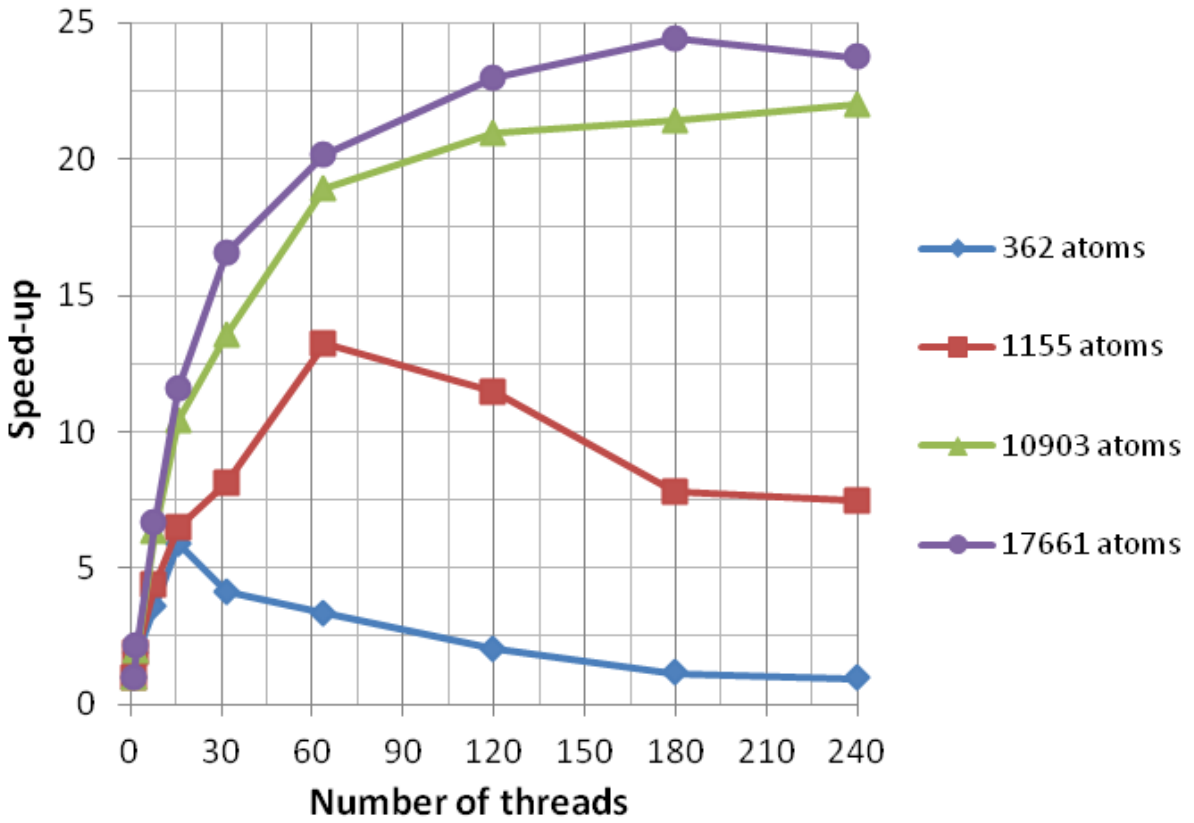


Резултати
C + OpenMP + Intel libraries
Intel Xeon CPU + Intel Xeon Phi (MIC)



Intel Xeon Host



Intel Xeon Phi Coprocessor

Публикации

- P. Petkov, D. Grancharov, S. Markov, G. Georgiev, E. Lilkova, N. Ilieva, L. Litov, *Massively parallel Poisson Equation Solver for hybrid Intel Xeon – Xeon Phi HPC Systems*, PRACE whitepapers, (2014) http://www.prace-ri.eu/IMG/pdf/wp143.pdf

- P. Petkov, E. Lilkova, S. Markov, D. Grancharov, N. Ilieva, L. Litov, *AGBNP2 Implicit Solvent Library for Intel® MIC Architecture*, PRACE whitepapers, (2014) http://www.prace-ri.eu/IMG/pdf/wp146.pdf

- D. Grancharov, E. Lilkova, N. Ilieva1, P. Petkov, S. Markov and L. Litov, *Analysis of symplectic integration algorithms with variable step size for petascale biomolecular simulations,* PRACE whitepapers, http://www.prace-ri.eu/IMG/pdf/analysis_of_symplectic_integration_algorithms_with_variable_step_size_for_petascale_biomolecular_simulations.pdf

Публикации

- G. Nacheva, E. Lilkova, P. Petkov, P.St. Petkov, N. Ilieva, I. Ivanov, and L. Litov, *In silico studies on the tability of human interferon-gamma mutants*, Biotechnology & Biotechnological Equipment, (2012) Vol 26(1), pp 200-204, DOI: 10.5504/50YRTIMB.2011.0036 (Impact Factor = 0.760)

- E. Lilkova, G. Nacheva, P. Petkov, P. St. Petkov, S. Markov, N. Ilieva, and L. Litov, *Metadynamics study of mutant human interferon-gamma forms*, Computers and Mathematics with Applications, (2012), Volume 64(3), pp 272-277, doi 10.1016/j.camwa.2012.01.061., (Impact Factor = 1.472).

- E. Lilkova, L. Litov, P. Petkov, P. St. Petkov, S. Markov, and N. Ilieva, *Computer simulations of human interferon gamma mutated forms,* AIP Conf. Proc., (2010) Vol. 1203, pp. 914-919, ISBN: 978-0-7354-0740-4, doi:http://dx.doi.org/10.1063/1.3322582.

Конференции

- Lilkova E, Petkov P, Grancharov D, Petkov PS, Ilieva N, Litov L, *Estimating protein-protein binding free energies by the unit interval approach*, Modelling and Design of Molecular Materials 2014, Kudowa-Zdrój, Poland – представяне на постер

- Lilkova E, Petkov P, Ilieva N, Grancharov D, Litov L, Petkov P, *Molecular Dynamics Simulations of Human Interferon Gamma*; Second National Congress in Physics, Sofia, 2013.

- Petkov P, Lilkova E, Grancharov D, Petkov PS, Ilieva N, Litov L, *Calculating Binding Free Energies of Variants of hIFN-g and their Extracellular Receptor*; International Conference on Mathematical Methods and Models in Biosciences, BIOMATH 2013, Sofia, Bulgaria, 2013

Благодаря за вниманието!