UNIVERSITY OF CAMBRIDGE

Pseudopotentials for a dipolar ultracold atomic gas

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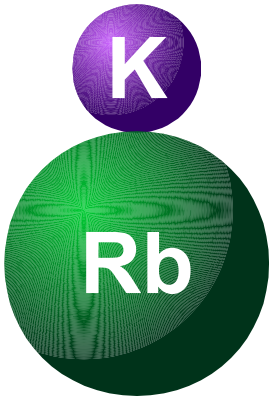
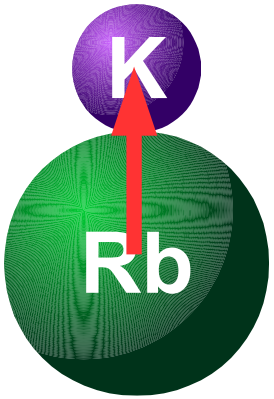
Dipolar molecule



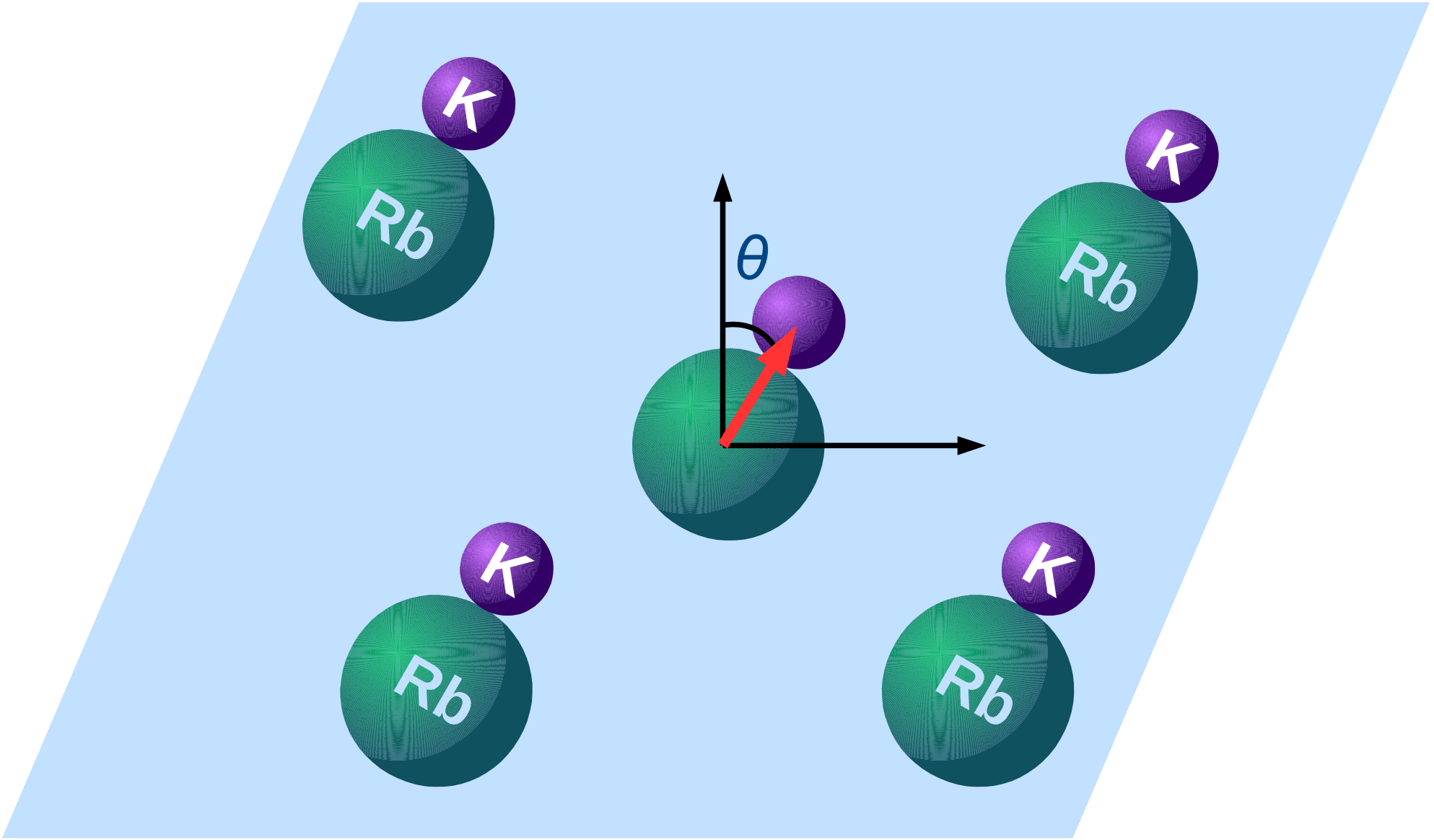
Ni et al., Nature 464, 1324 (2010)

Dipole moment



d ~ 0.5 Debye

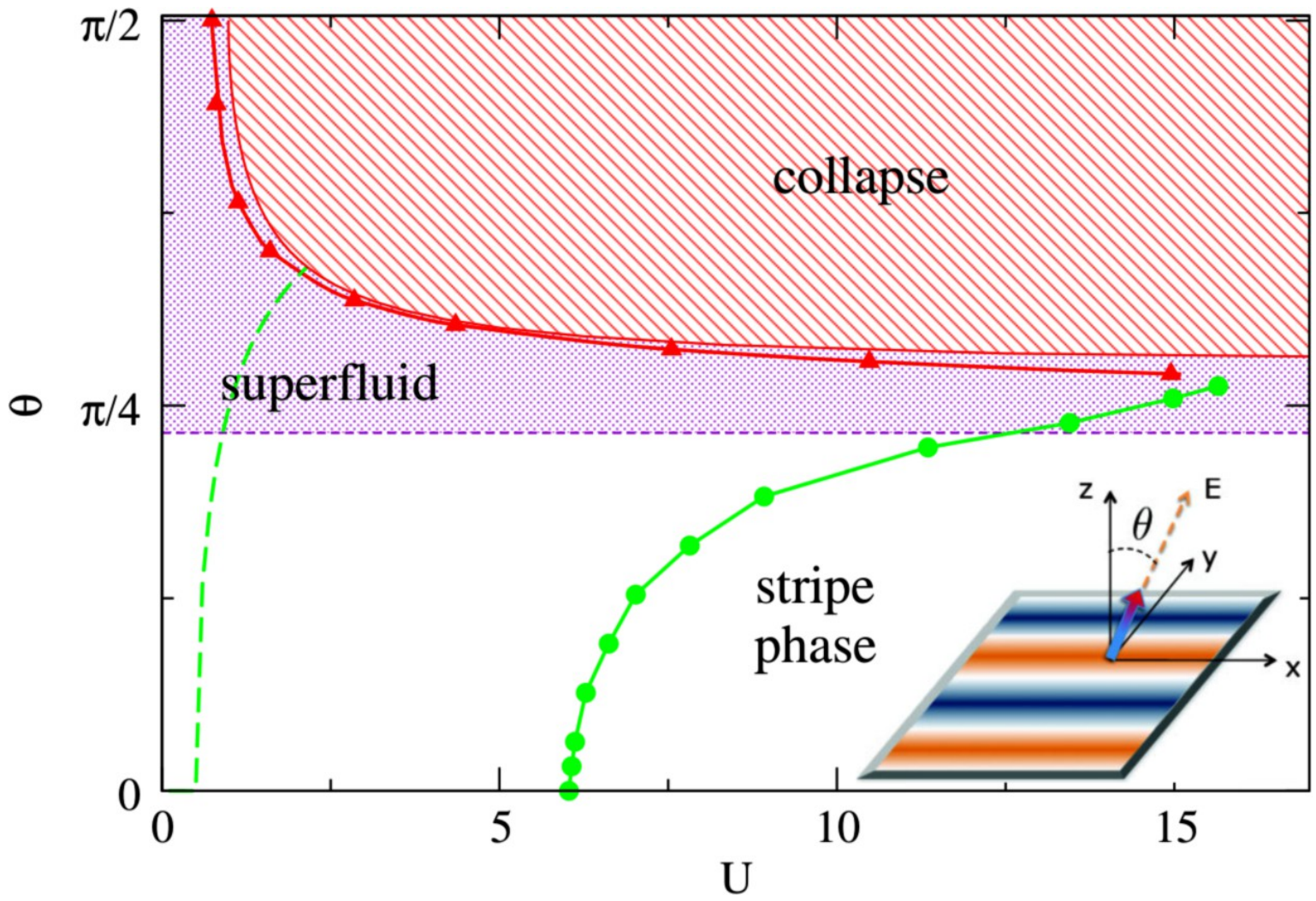
A 2D dipolar gas



Reasons for interest

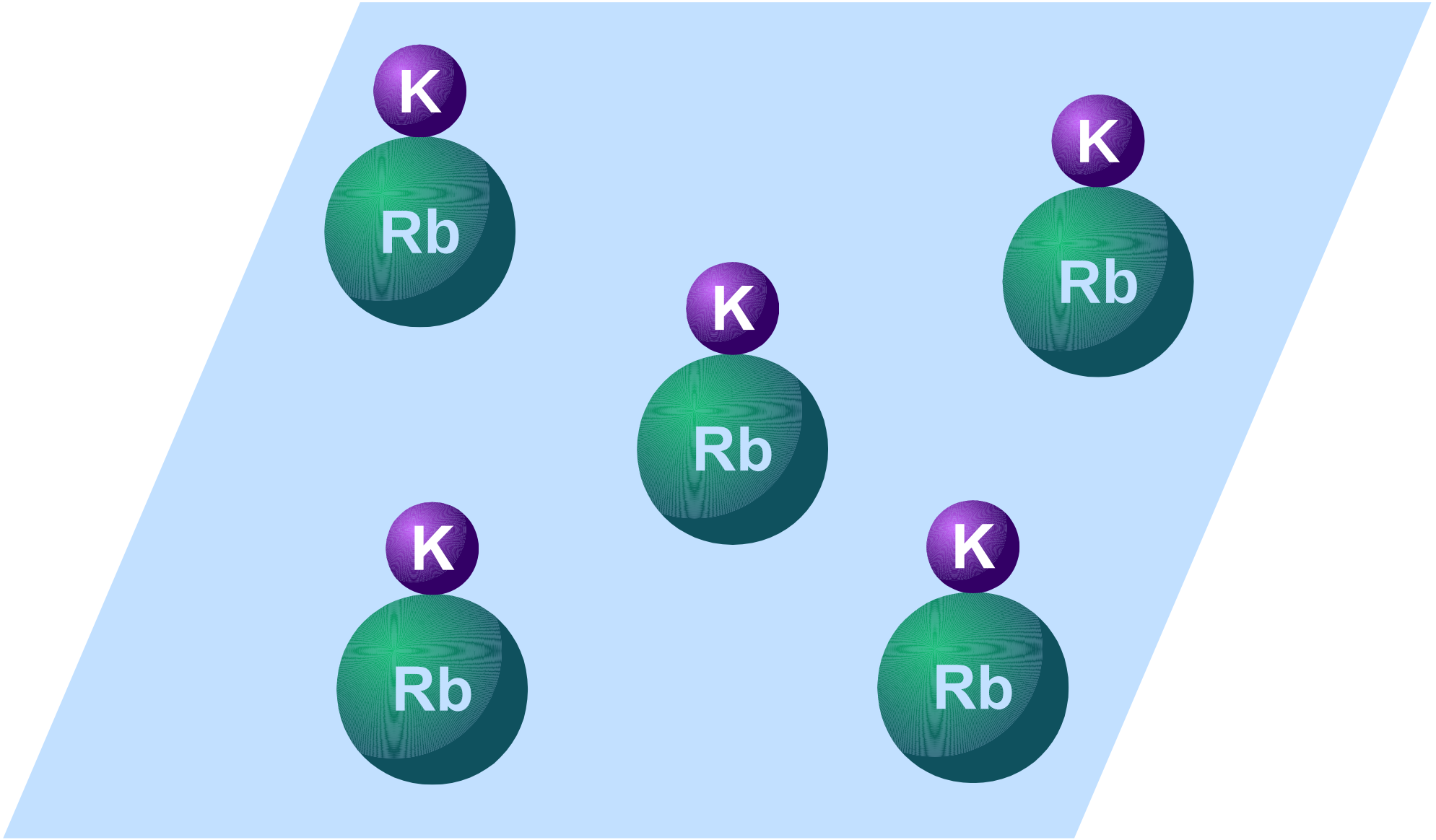
- Control of ultracold chemical reactions
- Quantum information processing
- Novel strongly correlated phases

Phase diagram

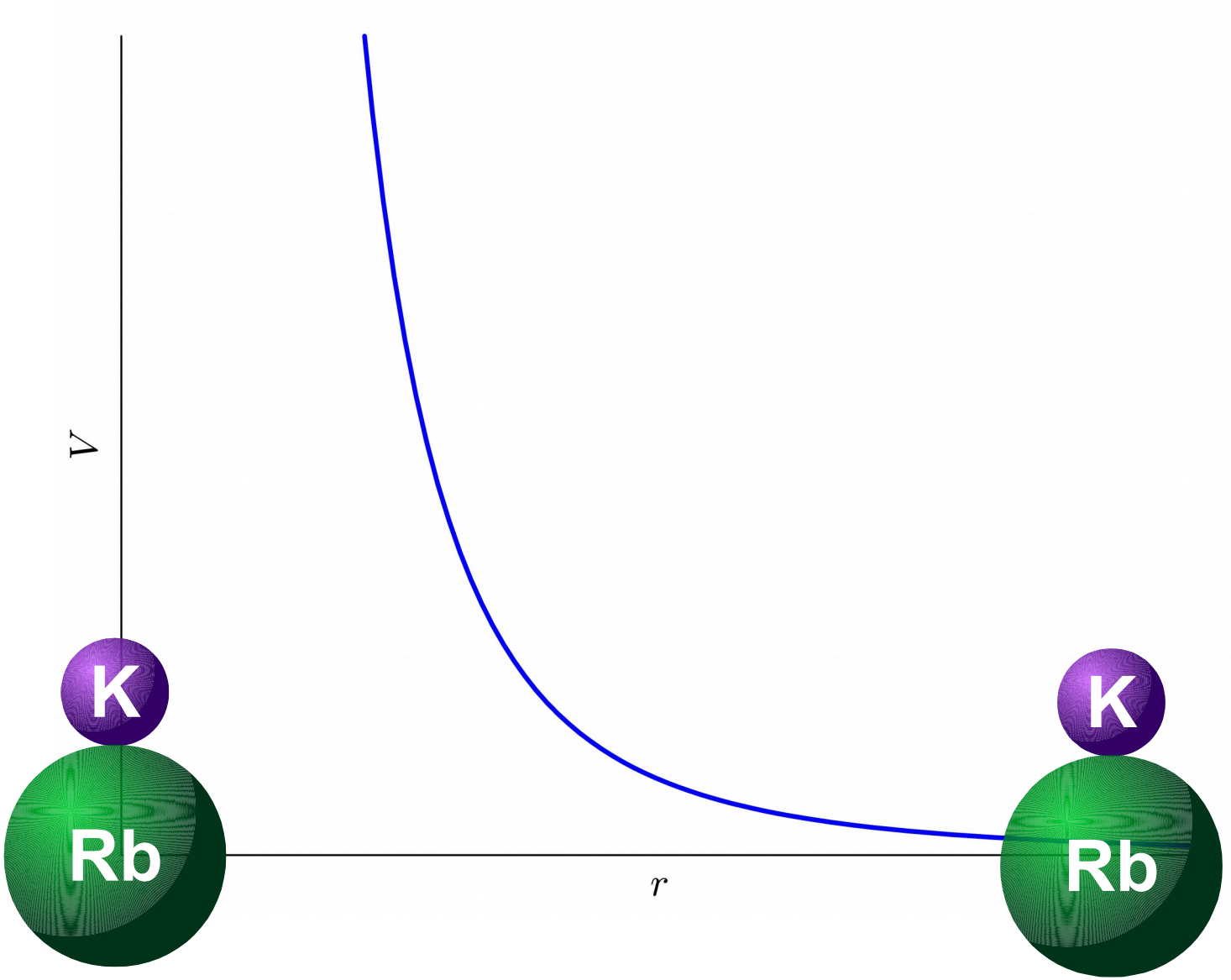


Parish and Marchetti, PRL 108, 145304 (2012)

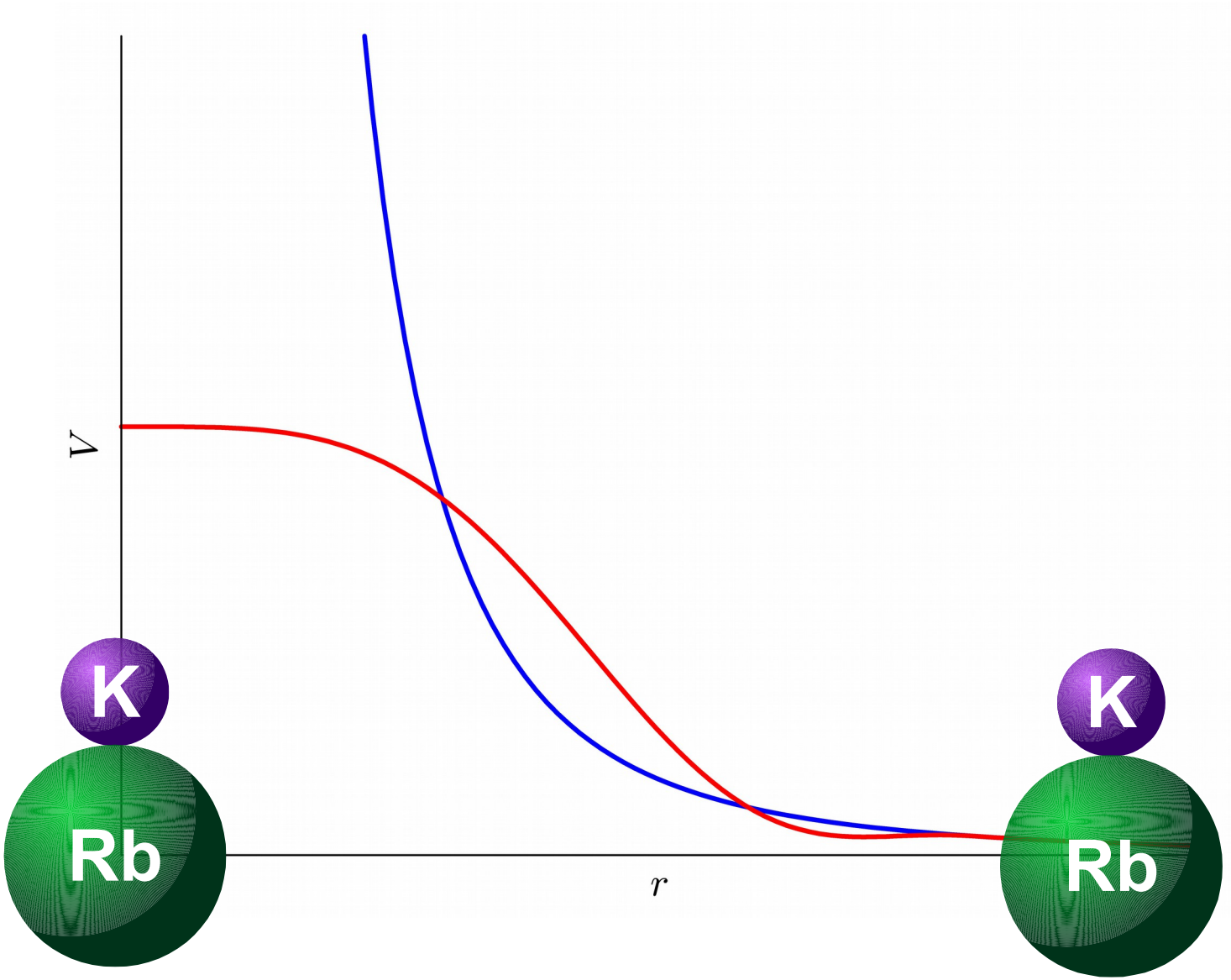
$\theta = 0$ case



Two interacting dipoles

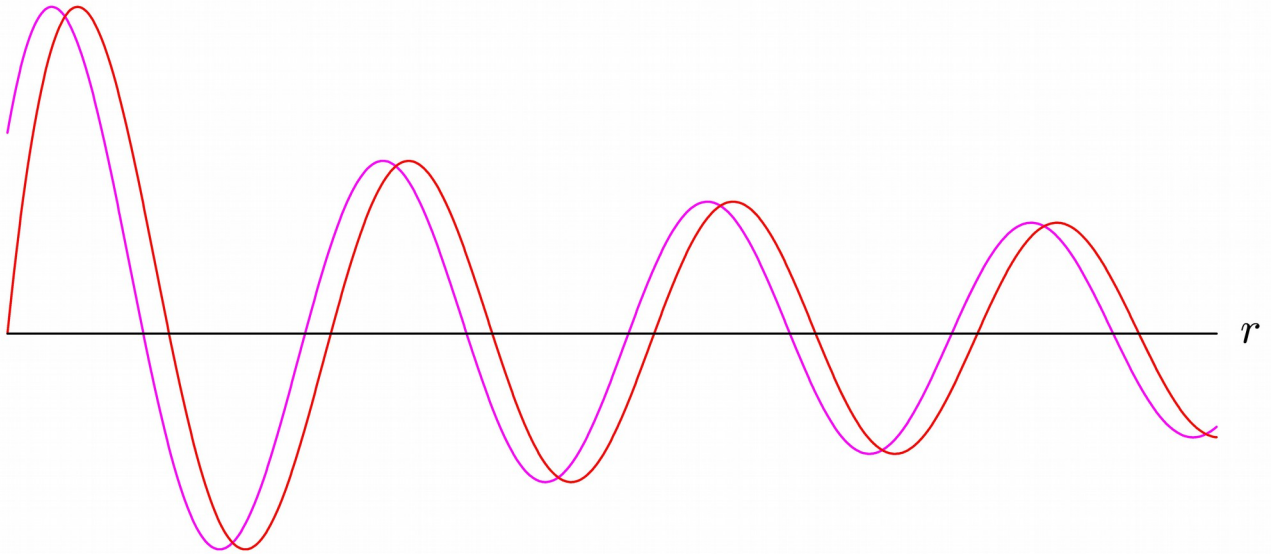


Two interacting dipoles

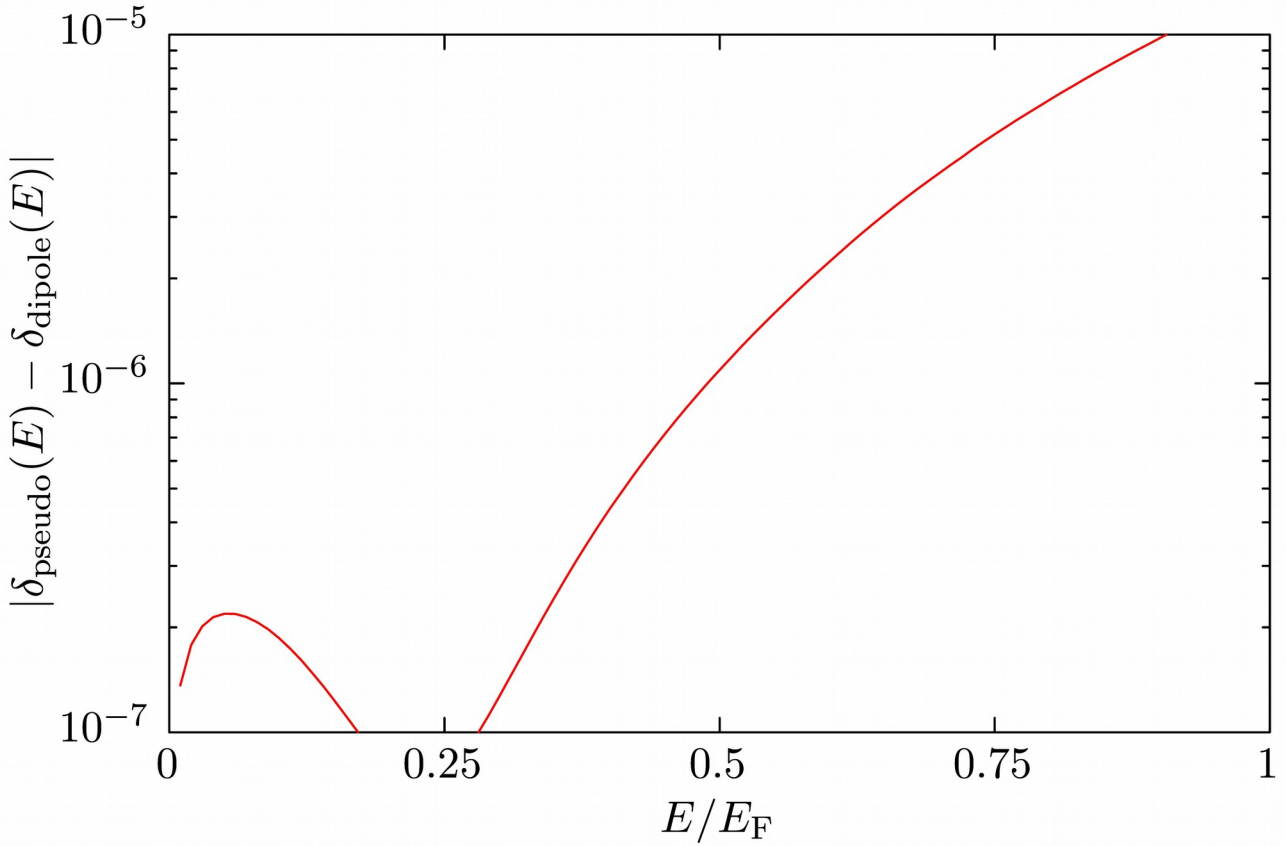


Bugnion, López Ríos, Needs & Conduit, Phys. Rev. A 90, 033626 (2014)

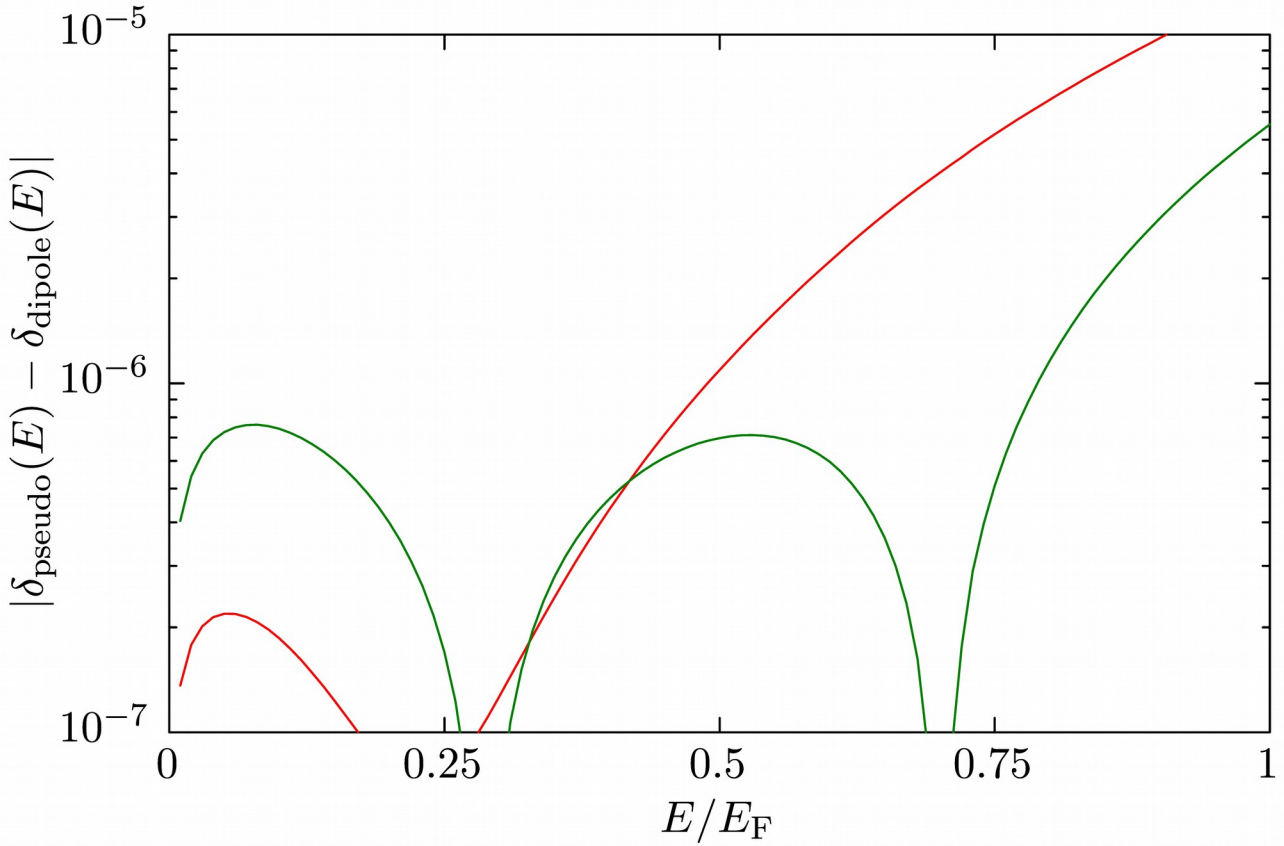
Phase shift error



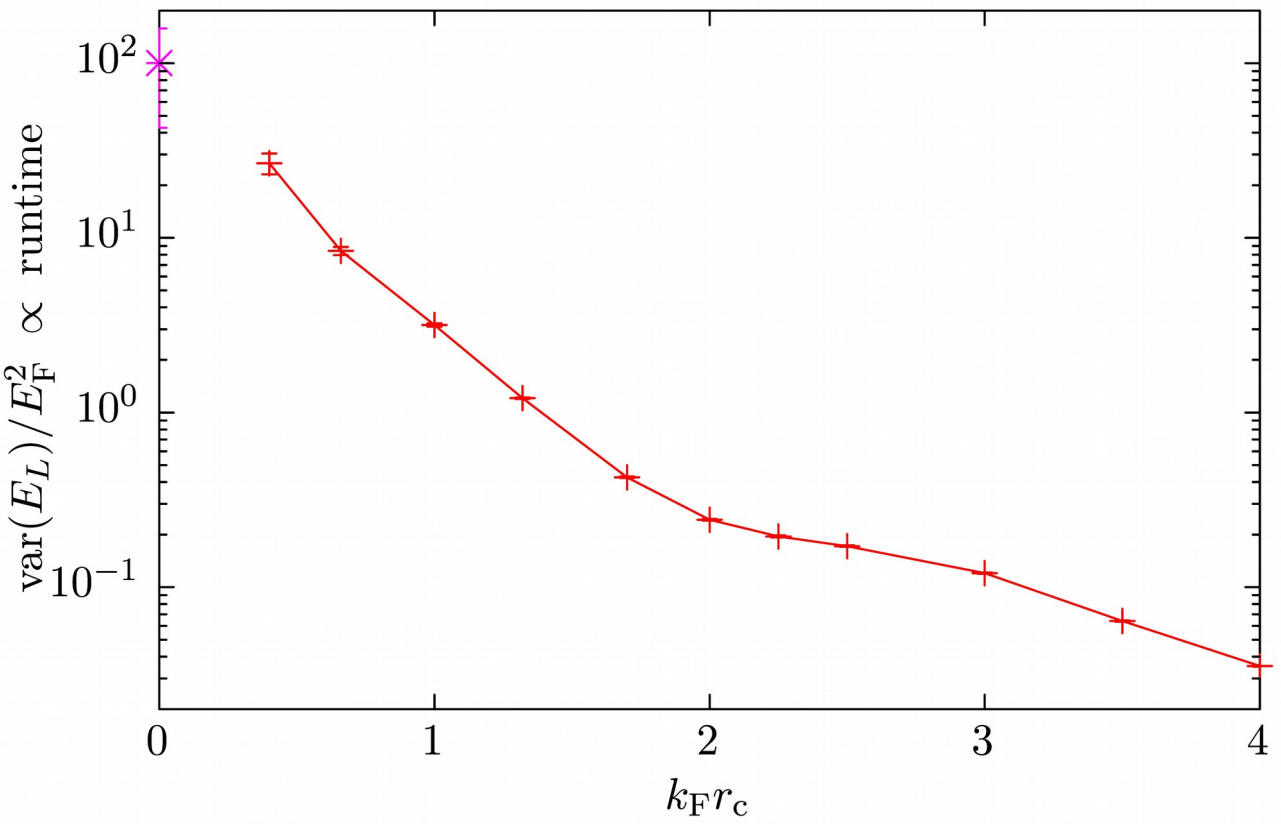
Phase shift error



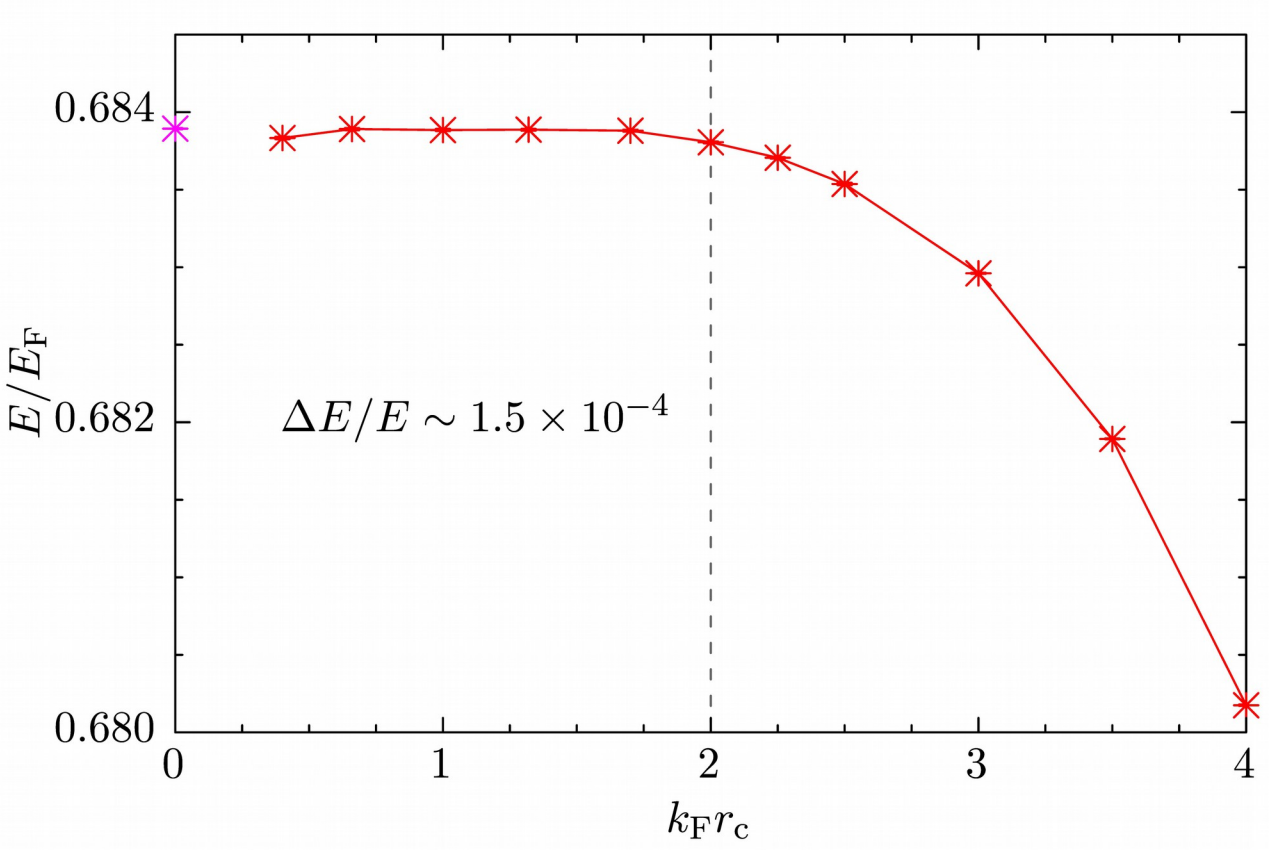
The ultratransferable pseudopotential



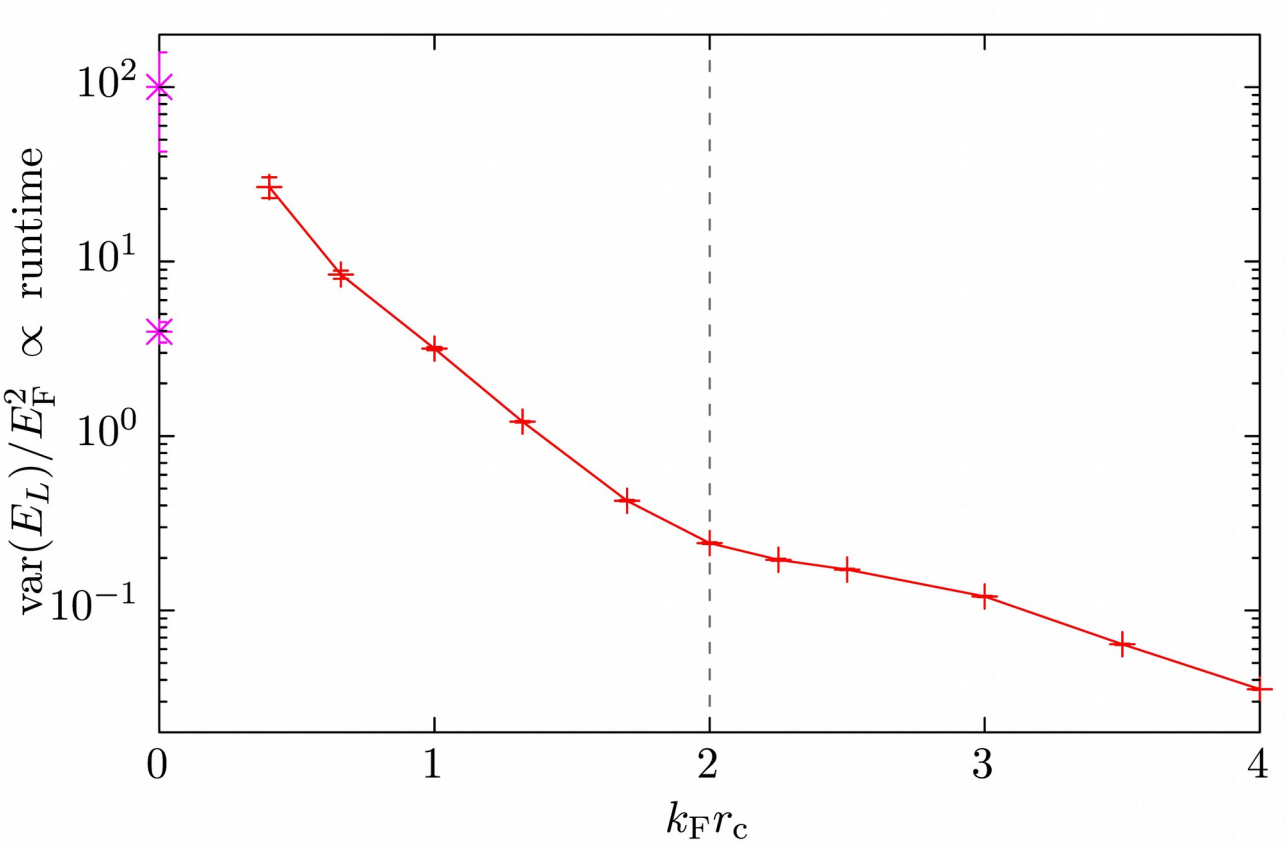
Runtime speed-up



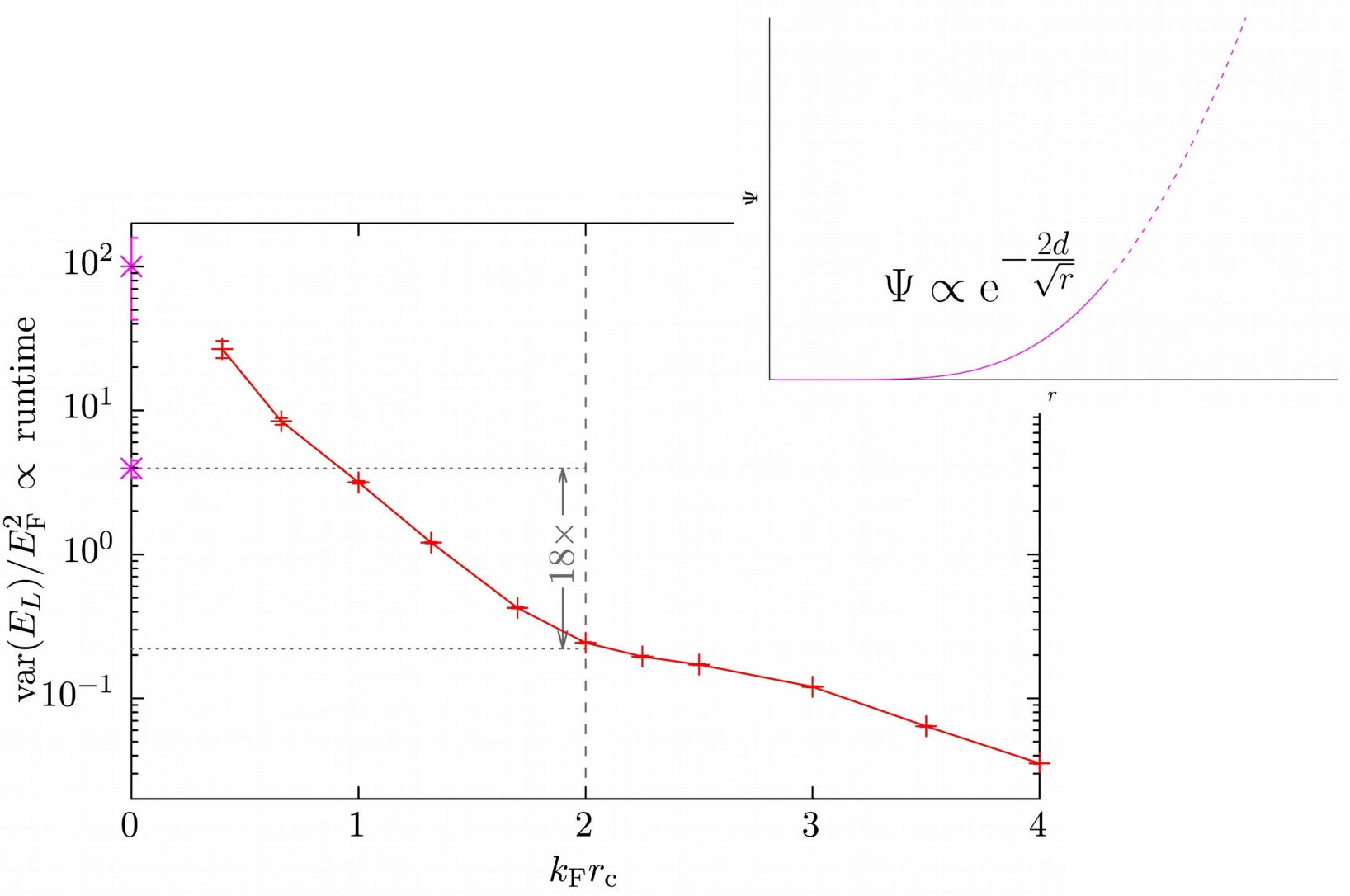
Change in energy with cutoff radius



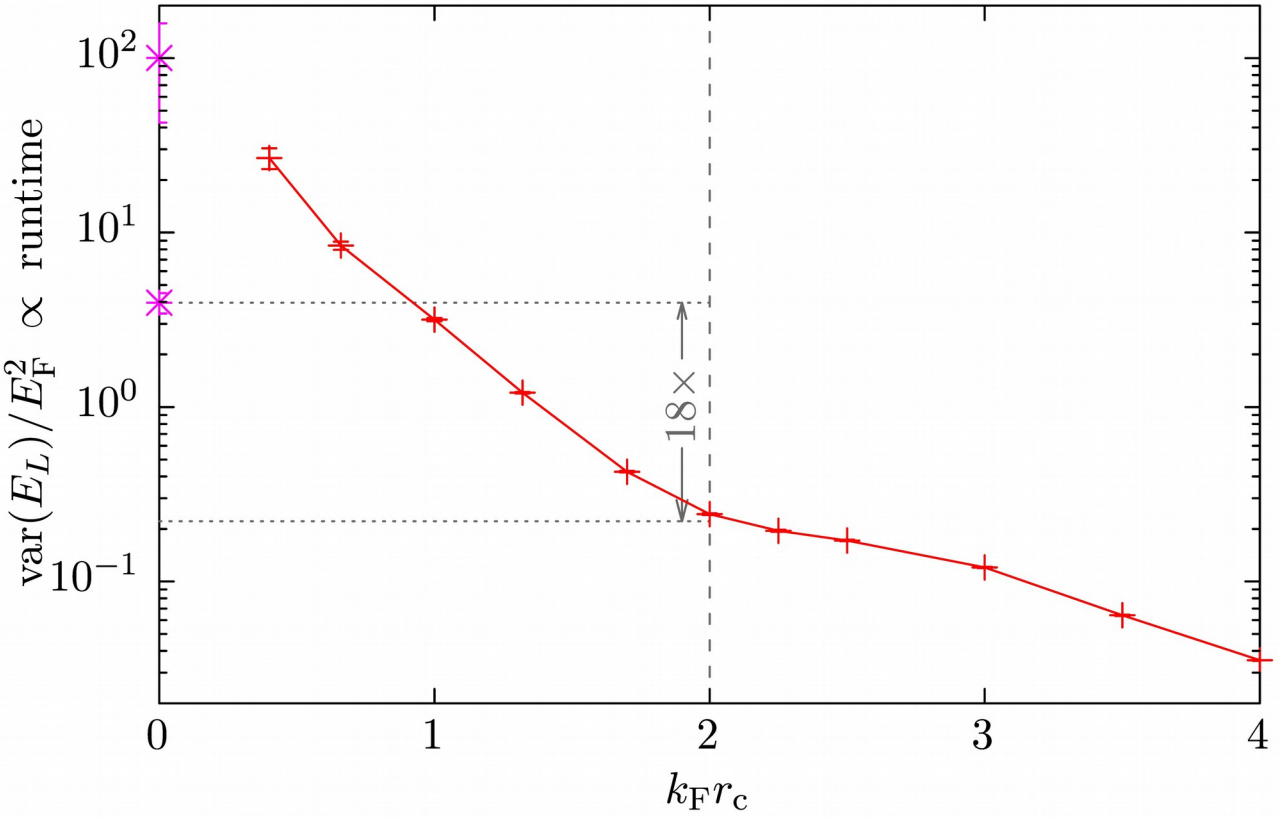
Runtime speed-up



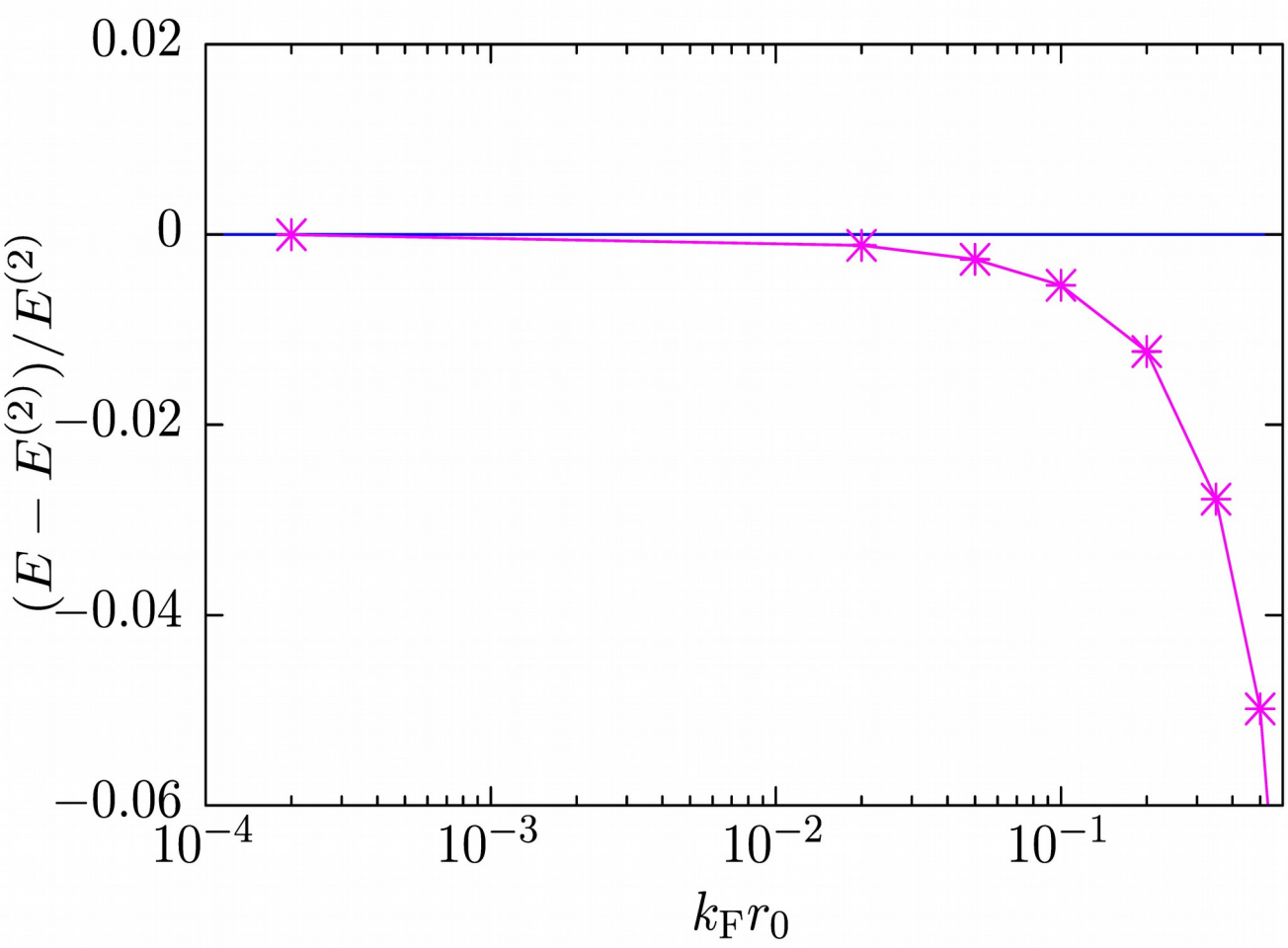
Runtime speed-up



Runtime speed-up



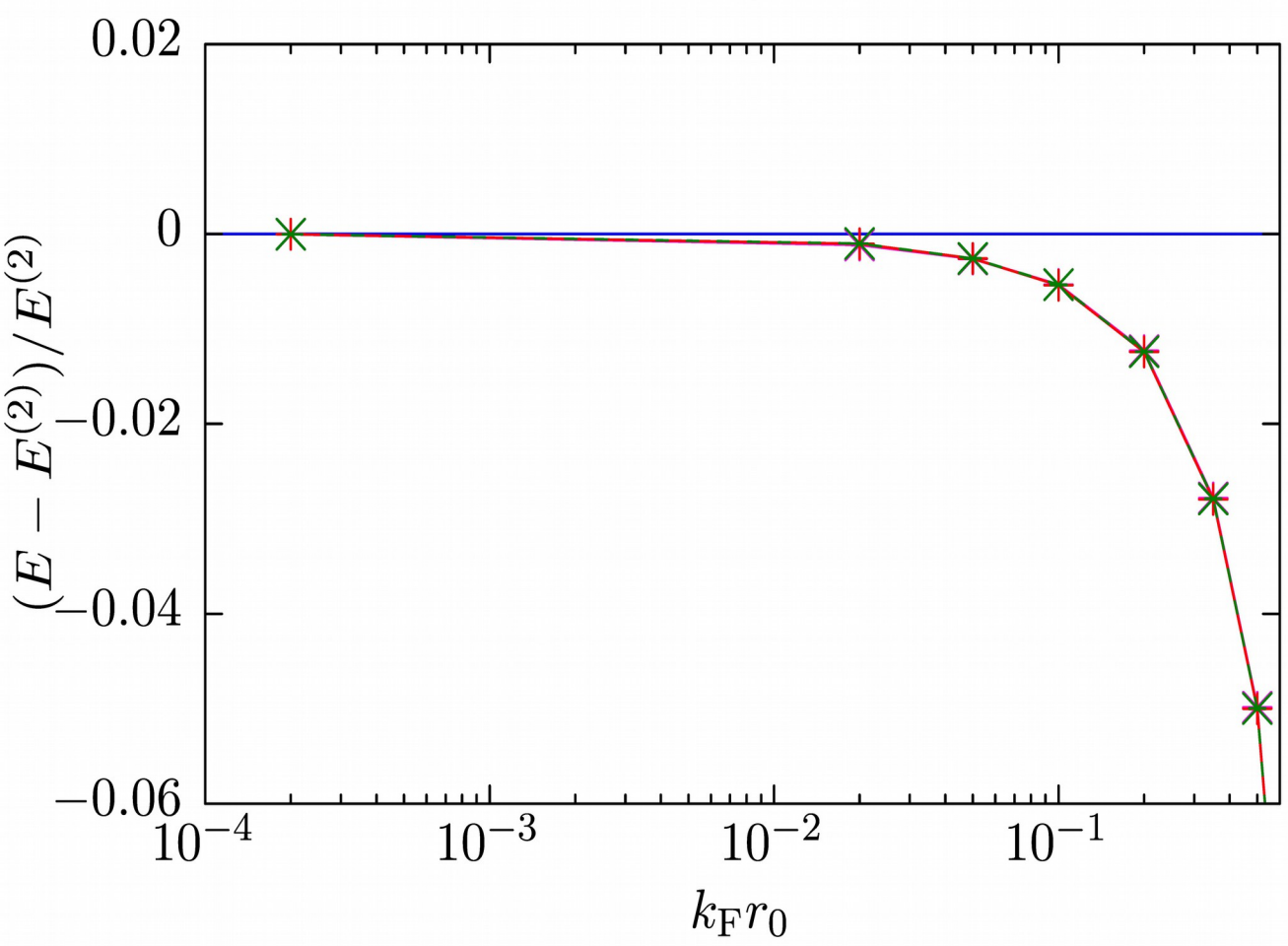
Equation of State



Perturbation theory

Dipole DMC

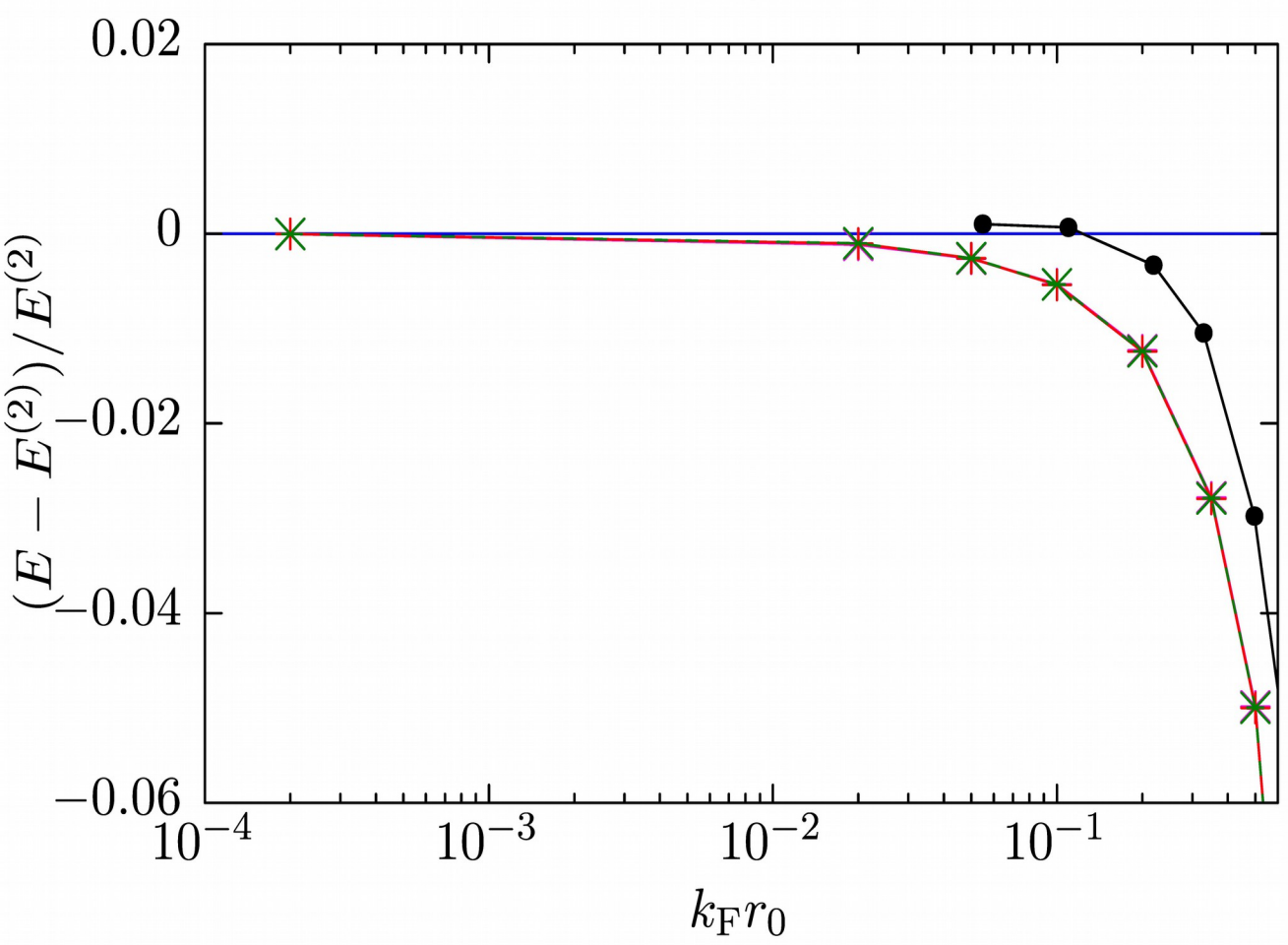
Equation of State



Perturbation theory

Dipole DMC,
Troullier-Martins and
UTP pseudopotentials

Equation of State

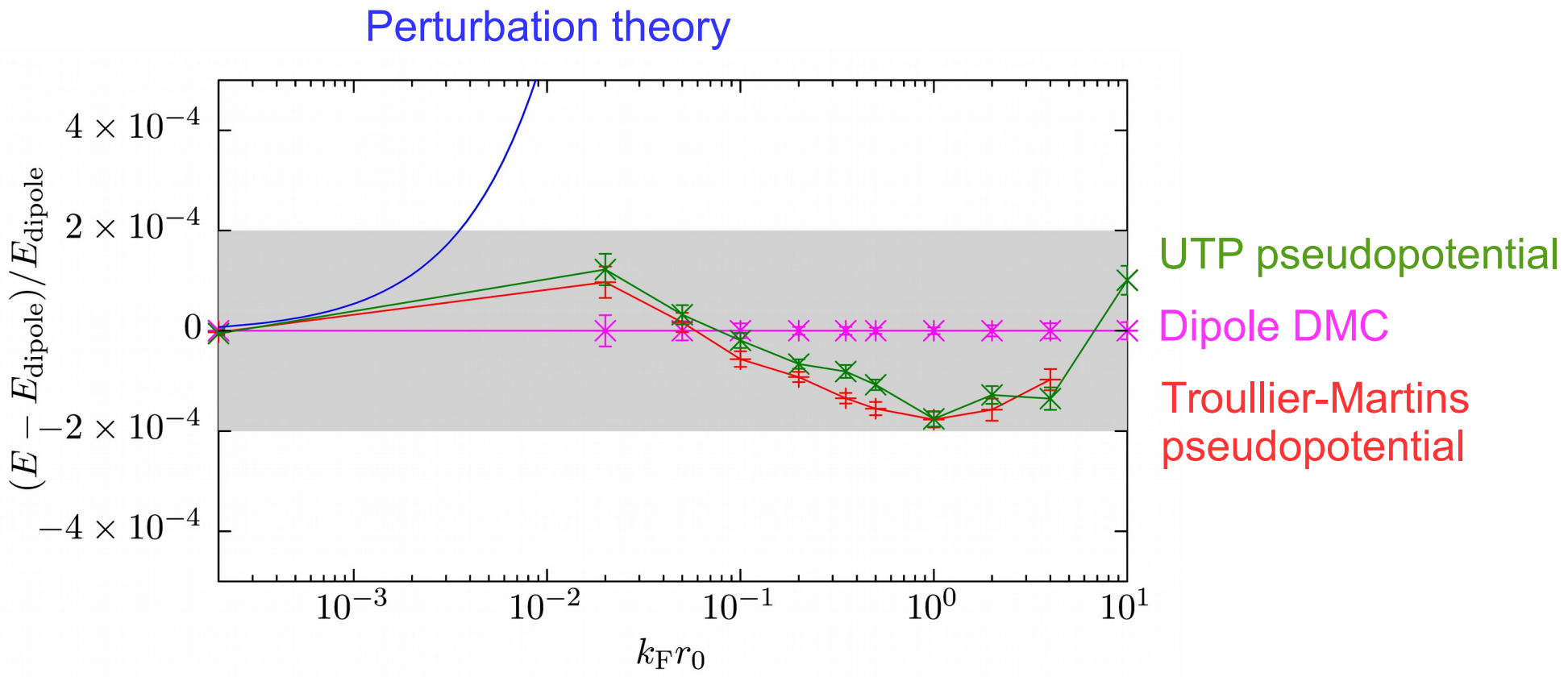


Perturbation theory

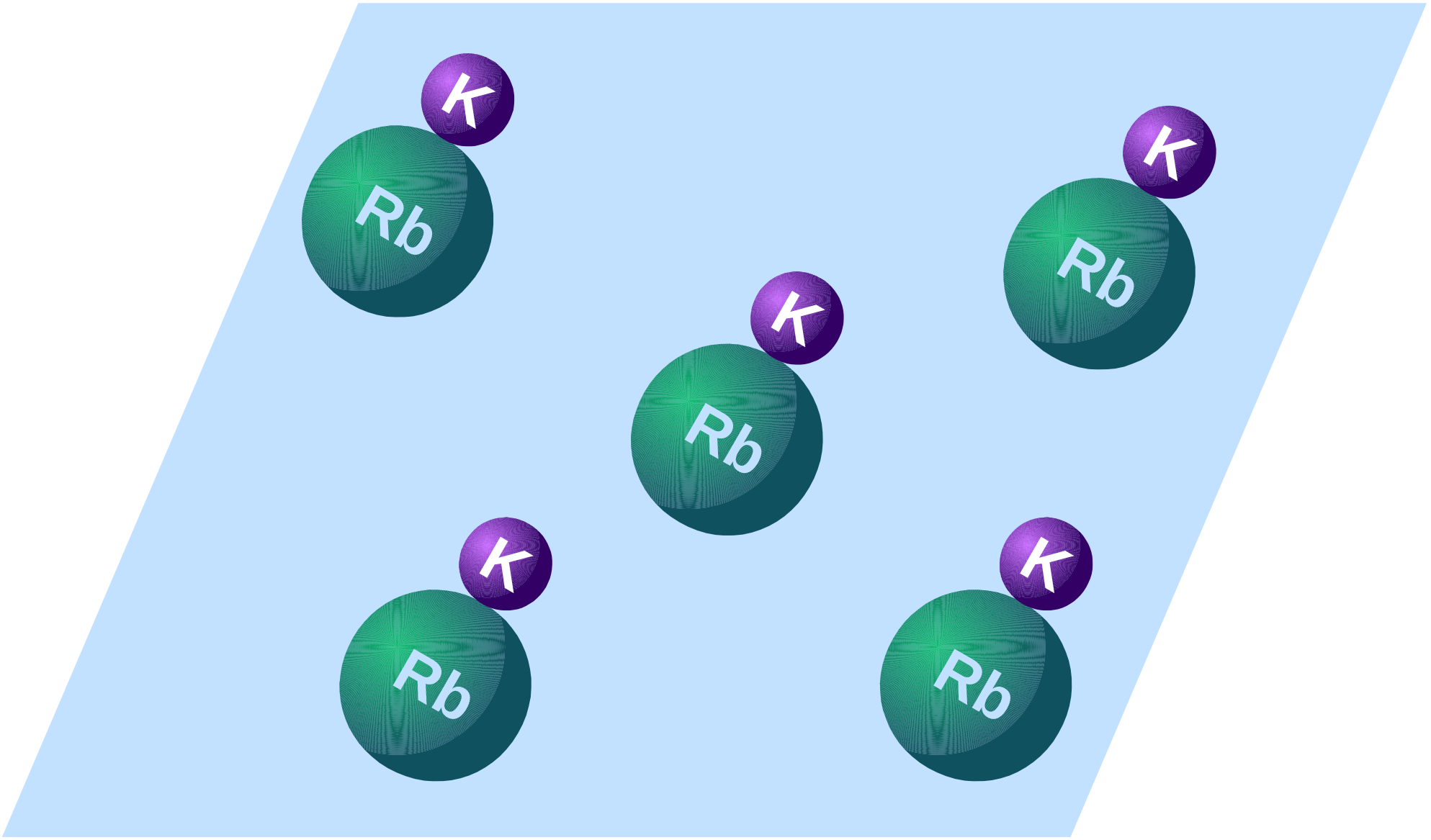
Matveeva and Giorgini
PRL 109, 200401 (2012)

Dipole DMC,
Troullier-Martins and
UTP pseudopotentials

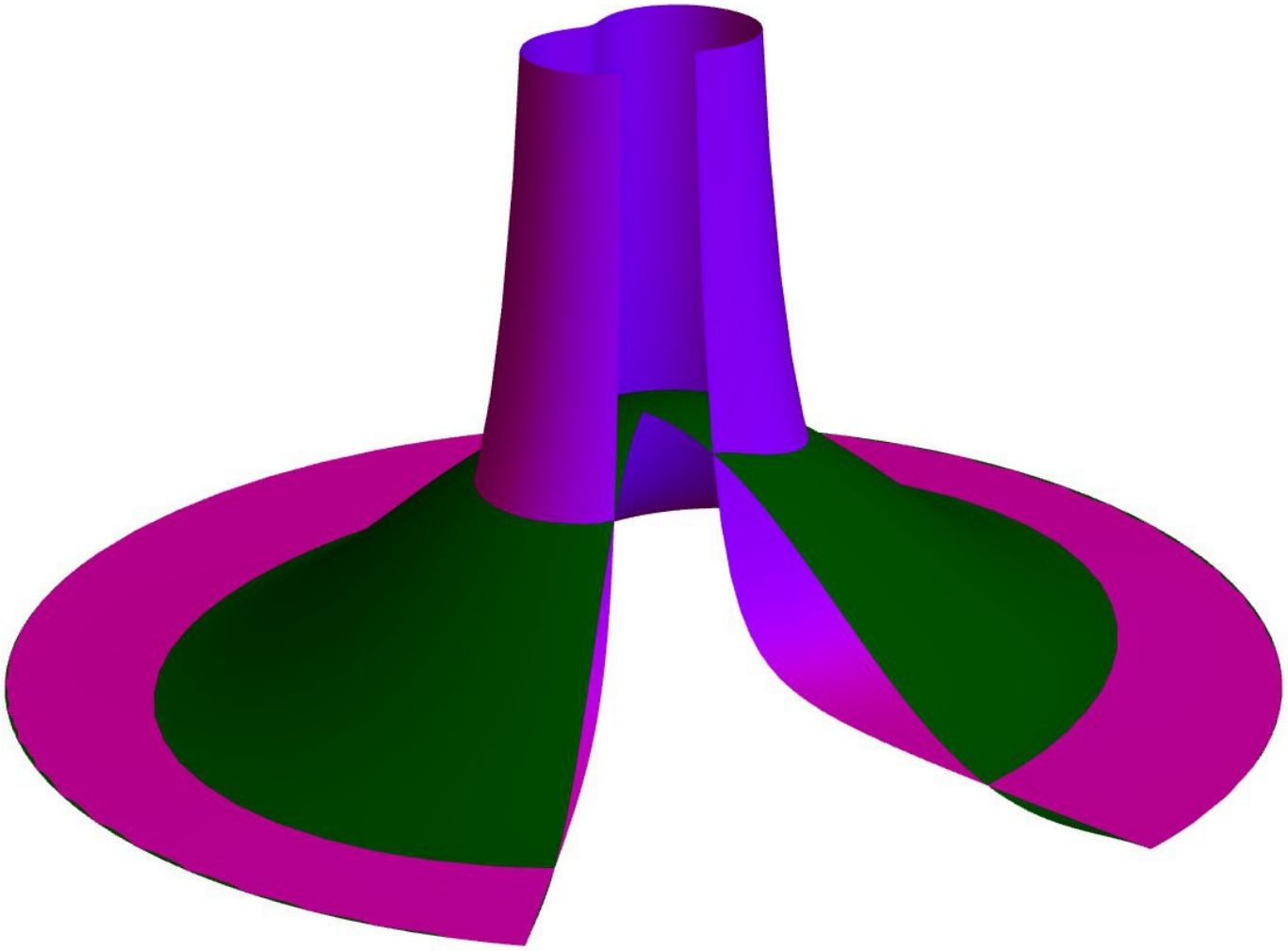
Accuracy of the pseudopotentials



Tilted dipoles



Tilted pseudopotential



Future possibilities

- Complete analysis of tilted pseudopotentials
- Investigate stripe phase, Wigner crystal
- Superfluid phase, few particles

Summary

- Constructed a pseudopotential for the dipolar interaction
- 10^{-4} accuracy
- 18x speed-up

“Kato” cusp conditions

$$E_{\mathrm{L}} = -\frac{1}{r}\frac{\Psi'}{\Psi} - \frac{\Psi''}{\Psi} + \frac{l^2}{r^2} + \frac{d^2}{r^3}$$

$$\Psi \propto r^{l} e^{J(r)}$$

$$E_{\mathrm{L}} = -\frac{2l+1}{r} J'(r) - J''(r) - \left(J'(r)\right)^2 + \frac{d^2}{r^3}$$

“Kato” cusp conditions