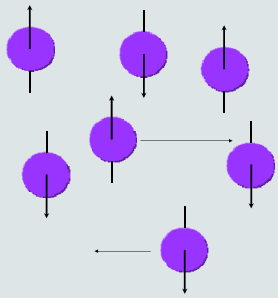
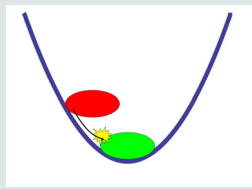
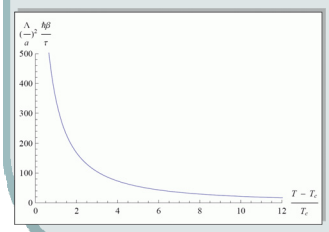
Spin Drag

$$\mathbf{F}_\uparrow = -\mathbf{F}_\downarrow$$



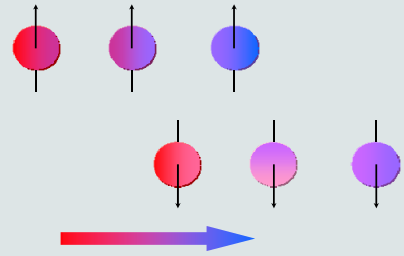




$$\sigma_{\uparrow\downarrow} = \frac{n\tau}{m}, \quad \Lambda = \sqrt{\frac{2\pi\hbar^2\beta}{m}}, \quad a = \text{scattering length}$$

• van Driel, Duine & Stoof, PRL **105**, 155301 (2010)
• Duine & Stoof, PRL **103**, 170401 (2009)

Spin-dependent Heat Transport



Why Bose Gases?

- Interested in transport properties of bosons
- Spin-Drag effect increases at low temperature for bosons, contrary to Fermions
- High degree of tunability: for instance, can put different temperature gradients on different species, and change interactions

Spin Caloritronics with Bose Mixtures

Hedwig van Driel, Rembert Duine, Henk Stoof (ITF, University of Utrecht)

Spin Current

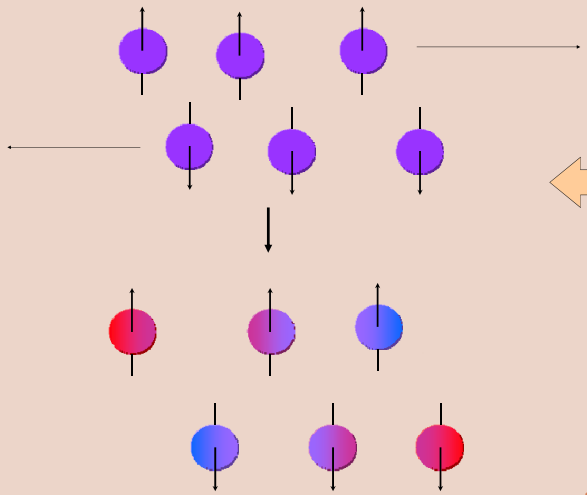
Heat Currents

$$\begin{pmatrix} \mathbf{j}_{\text{spin}} \\ \mathbf{j}_{Q_\uparrow} \\ \mathbf{j}_{Q_\downarrow} \end{pmatrix} = \begin{pmatrix} \sigma_{\uparrow\downarrow} & \sigma_{\uparrow\downarrow} TS_\uparrow & \sigma_{\uparrow\downarrow} TS_\downarrow \\ \sigma_{\uparrow\downarrow}\Pi_\uparrow & T\kappa_{\uparrow\uparrow} & T\kappa_{\uparrow\downarrow} \\ \sigma_{\uparrow\downarrow}\Pi_\downarrow & T\kappa_{\downarrow\uparrow} & T\kappa_{\downarrow\downarrow} \end{pmatrix} \begin{pmatrix} \mathbf{F}_{\text{spin}} \\ -\frac{\nabla T_\uparrow}{T} \\ -\frac{\nabla T_\downarrow}{T} \end{pmatrix}$$

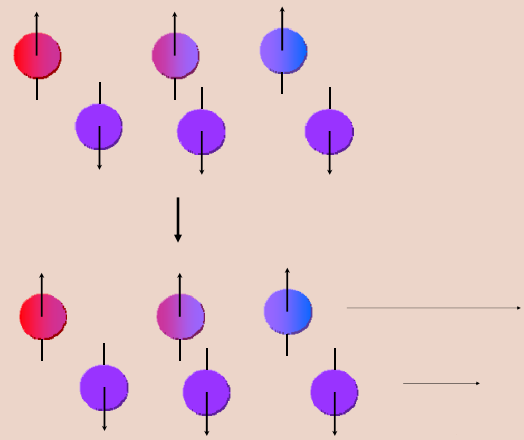
Spin dependent External Force

Temperature Gradients

Spin-dependent Peltier effect



Spin-dependent Seebeck effect



Work in progress: determine Peltier and Seebeck coefficients, and heat conductivity.