Consider an atom with:

- $F=1/2$ in ground level.
- $F'=3/2$ in excited level.

**Ground state:** $F = 1/2$

**Excited state:** $F' = 3/2$

$$m_{F'} = -\frac{3}{2}$$

$$m_F = -\frac{1}{2}$$

[figure adapted from *Atomic Physics* by C. Foot, Oxford U. Press (2006)]
Multi-level atom

Consider an atom with:
- $F=1/2$ in ground level.
- $F'=3/2$ in excited level.

**Excited state:** $F'=3/2$

\[
\begin{align*}
m_F' &= \frac{-3}{2} \\
\end{align*}
\]

Proportional to $\mu_{eg}^2$ or $\Omega^2$

**Ground state:** $F=1/2$

\[
\begin{align*}
m_F &= \frac{-1}{2} \\
\end{align*}
\]

[figure adapted from *Atomic Physics* by C. Foot, Oxford U. Press (2006)]
AC Stark Shift in Polarization Gradient Lattice

[figure adapted from Atomic Physics by C. Foot, Oxford U. Press (2006)]
**AC Stark Shift in Polarization Gradient Lattice**

![Diagram](image)

**Excited state:** \( F' = 3/2 \)

\[
\begin{align*}
    m_{F'} &= -\frac{3}{2} \\
    -\frac{1}{2} & \quad \frac{1}{2} \\
    \frac{2}{3} & \quad \frac{1}{3} \\
    \frac{3}{2} & \quad 1
\end{align*}
\]

**Ground state:** \( F = 1/2 \)

\[
\begin{align*}
    m_F &= -\frac{1}{2} \\
    \frac{1}{2} & \quad -\frac{1}{2} \\
    \frac{1}{3} & \quad \frac{2}{3} \\
    1 & \quad 1
\end{align*}
\]

**AC Stark shift for red detuning**

[figure adapted from *Atomic Physics* by C. Foot, Oxford U. Press (2006)]
Sisyphus Cooling

Ground state: $F = 1/2$

Excited state: $F' = 3/2$

$m_F = \pm 1/2$

$m_{F'} = \pm 3/2$

$\hbar \omega_{\text{abs}} \quad \hbar \omega_{\text{em}}$

$\sigma^+ \quad \sigma^- \quad \sigma^+ \quad \sigma^- \quad \sigma^+$

[figure adapted from *Atomic Physics* by C. Foot, Oxford U. Press (2006)]
Atoms that are excited at the top of a hill are most likely to decay to valley.

[figure adapted from Atomic Physics by C. Foot, Oxford U. Press (2006)]
Atoms that are excited at the top of a hill are most likely to decay to valley.

Excited state: $F' = 3/2$
$F' = \frac{3}{2}$
$\frac{1}{2}$
$\frac{3}{2}$
$\frac{2}{3}$
$\frac{1}{3}$
$\frac{1}{2}$
$\frac{3}{2}$

Ground state: $F = 1/2$
$m_F = \frac{1}{2}$
$m_F = \frac{-1}{2}$
$m_F = +1/2$
$m_F = -1/2$

atoms travel uphill most of the time $\rightarrow$ cooling

[f]igure adapted from *Atomic Physics* by C. Foot, Oxford U. Press (2006)
Cooling Force (Doppler + Sisyphus)

Doppler force

Sisyphus force

\[ s_0 = 0.5 \]
\[ \delta = 1.5 \gamma \]

[figure adapted from Laser Cooling and Trapping by H. Metcalf and P. van der Straten, Springer (1999)]