Sisyphus cooling

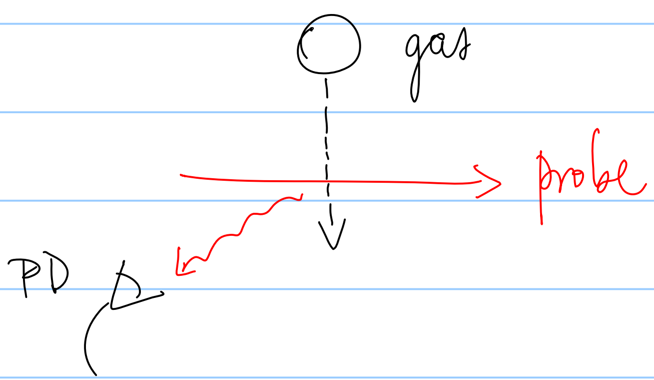
Note Title 4/6/2005

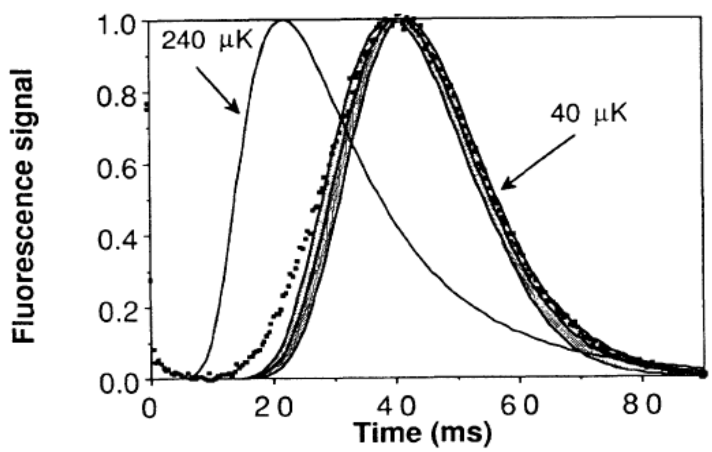
Experiments

1978 – ion trap – Wineland

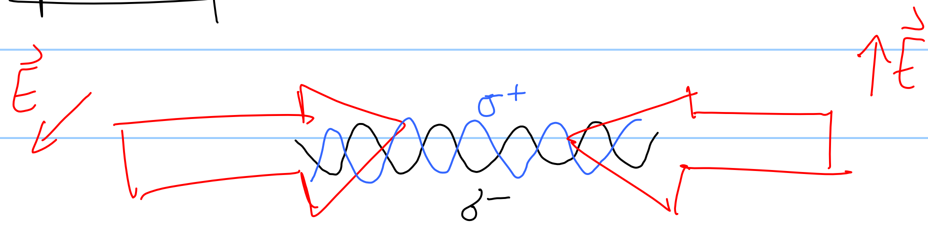
1985 – 3-D molasses – Chu et al
– temperature measurements $\sim T_D$

1988 – 3-D molasses, Na atoms
– better temperature measurements – 40 μK !



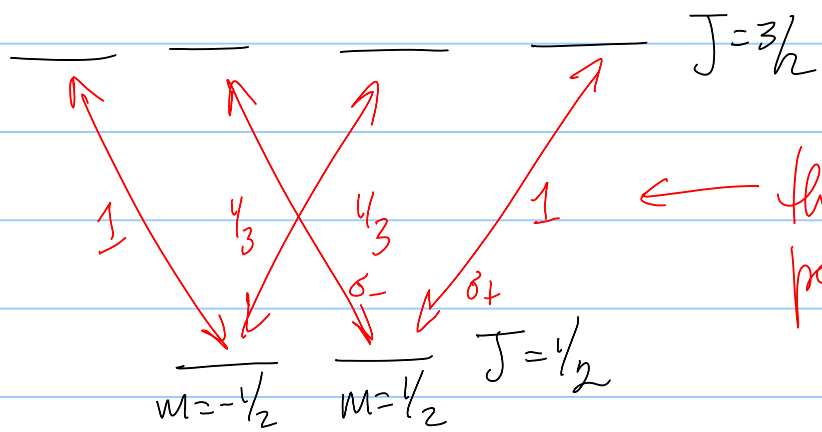


New theory of polarization gradient cooling (Dalibard & Cohen-Tannoudji and others) simplest picture:



lin $\perp$ lin configuration

$J = 1/2 \leftrightarrow 3/2$ transition



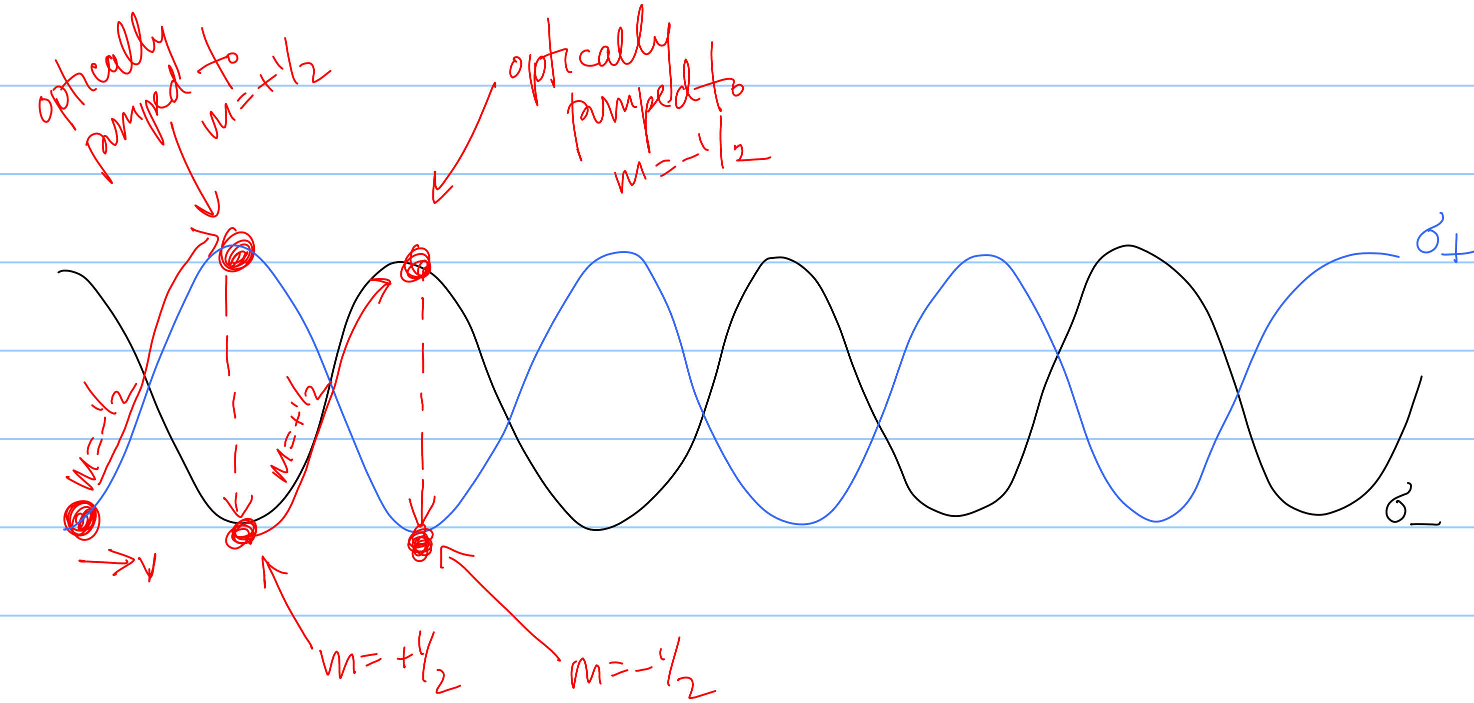
the angular momentum part of $|\langle g|\hat{\varepsilon}\cdot\vec{r}\,|e\rangle|^2$

So: $m = \pm 1/2$ more strongly coupled to $\sigma_\pm$ light

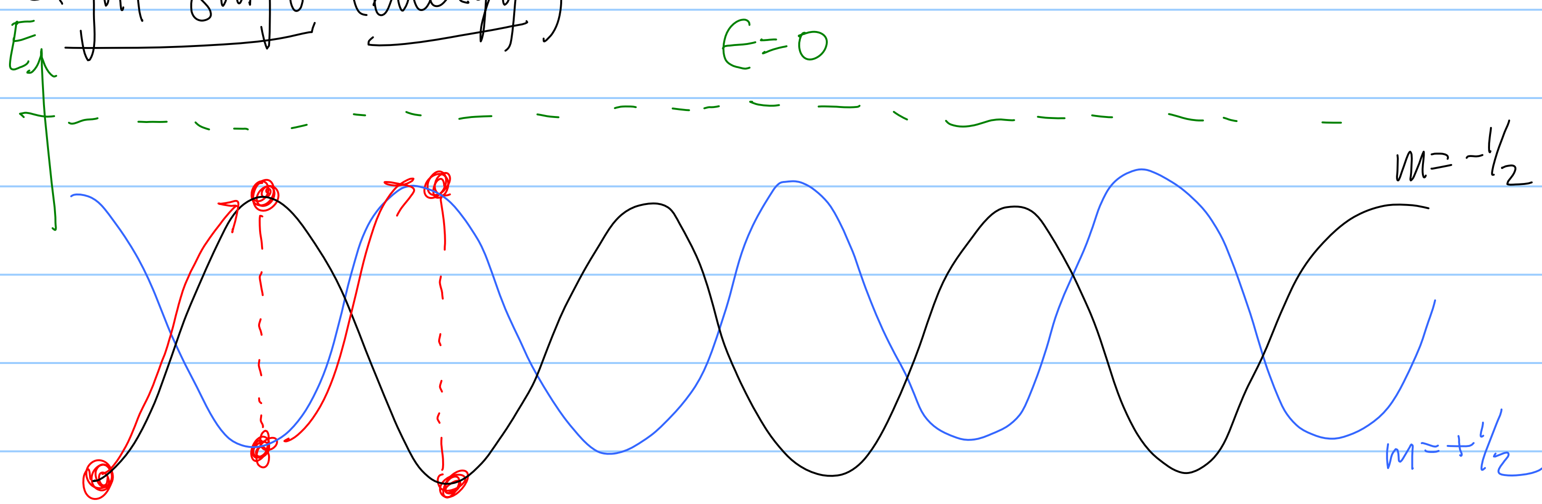
For $\delta < 0$ (red detuning), cooling occurs because of the interplay of the light shifts and optical pumping.

(Remember $\Delta E \propto 1/\delta$)

Intensity:



Light shift (energy)



energy is lost! for large detuning, $\Delta E \sim \hbar \frac{\Omega^2}{4\delta}$ just $|\Omega|^2$

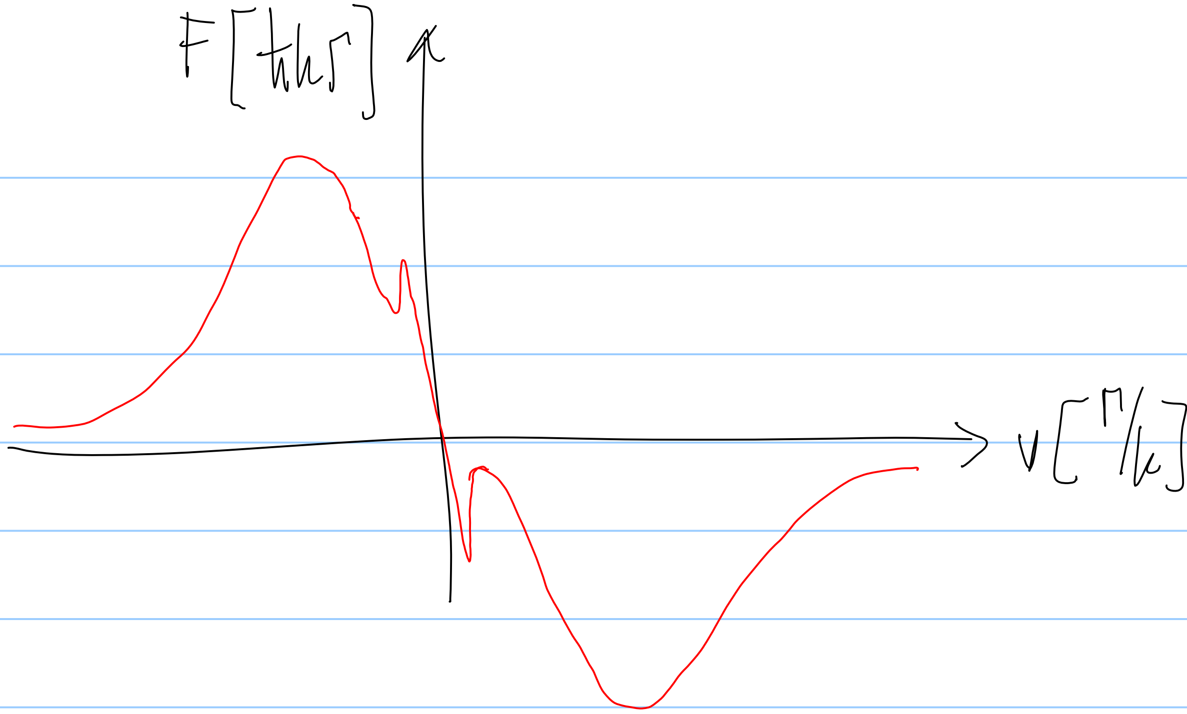
We call this "Sisyphus cooling." Entropy is again leaving through spontaneous emission (specifically spontaneous Raman scattering).

This force only takes over at small velocities:

$v \sim \frac{R}{k}$ ← opt. pumping rate
← length scale over which the pol changes

(the spin has to change on the same length scale as the polarization)

The friction force can be larger than for Doppler cooling at large detunings!



With larger α, the temperature limit is lower (closer to recoil limit) – can see a few μK in Cs (about 10x recoil limit)

Magneto-optic Trap (MOT)

- basic starting point for ultra-cold atom gas experiments
- magnetic field gradient added to 3-D optical molasses to make the optical force spatially dependent