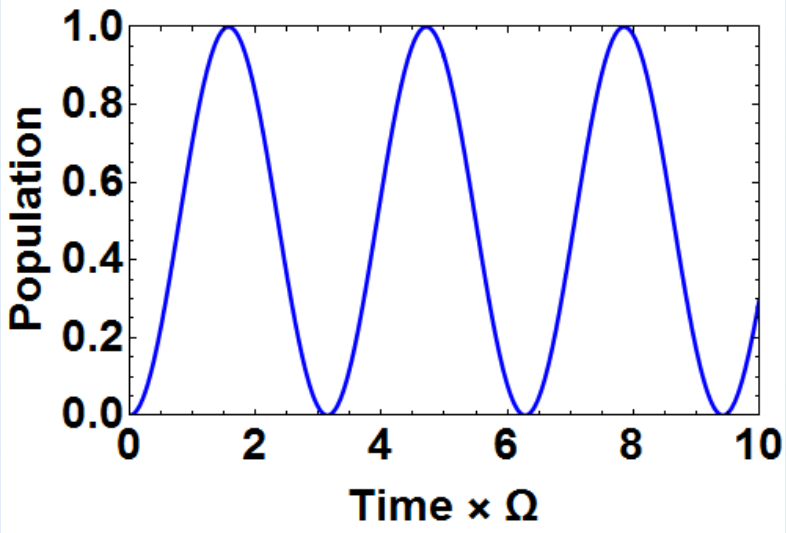
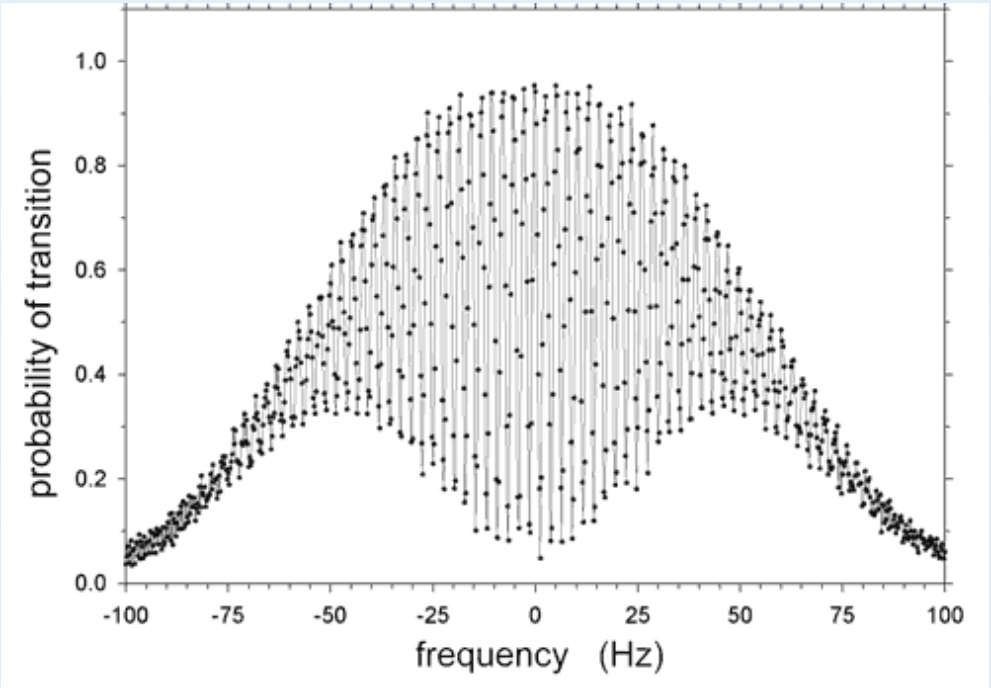
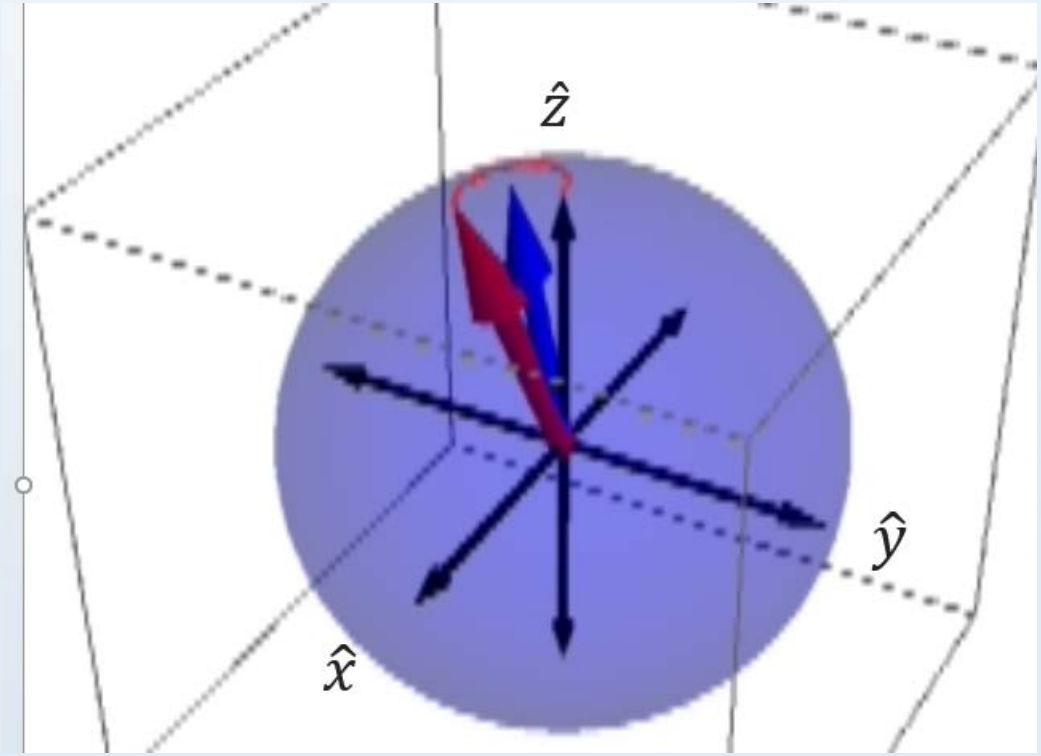
L8: 2-level systems – Rabi & Ramsey methods





How can we get the spin to keep going towards the "south pole," i.e. -z?



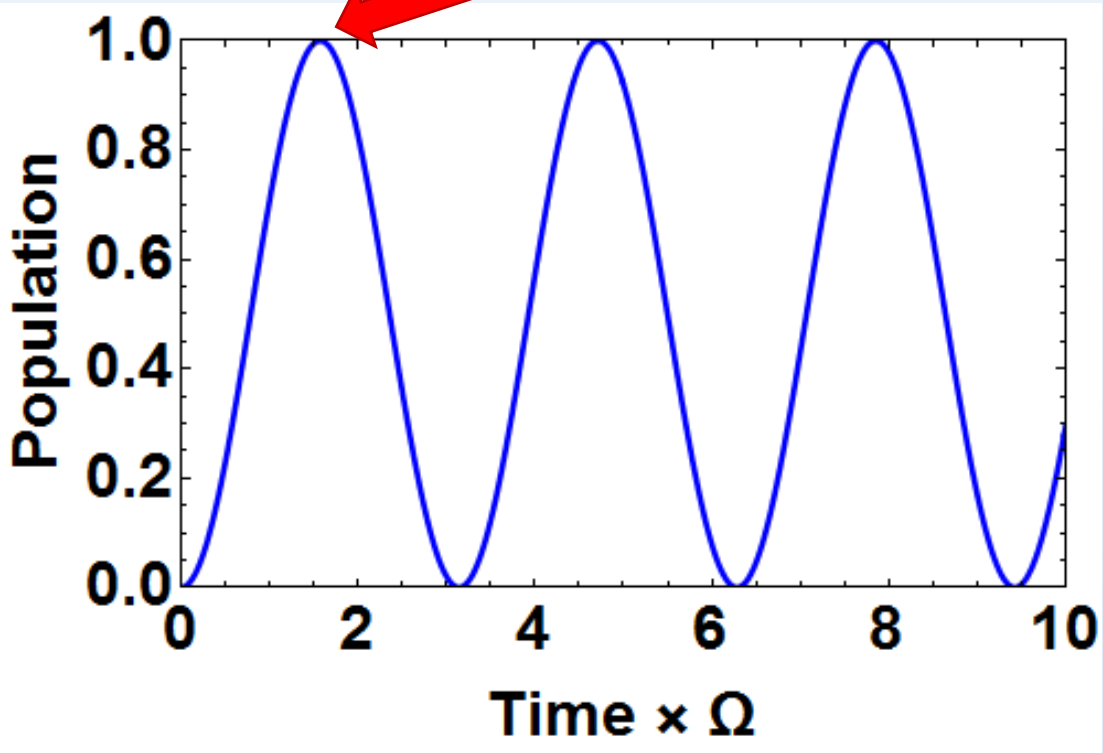
Follow up to last class:
Suggested method -- slowly sweep the field direction

Rabi dynamics

$$t^* = \frac{\pi}{2\Omega}$$

$$P(t) = \left|\frac{\Omega}{\Omega'}\right|^2 \sin^2(\Omega' t/2)$$

$$\Omega' = \sqrt{\Omega^2 + (\delta/2)^2}$$

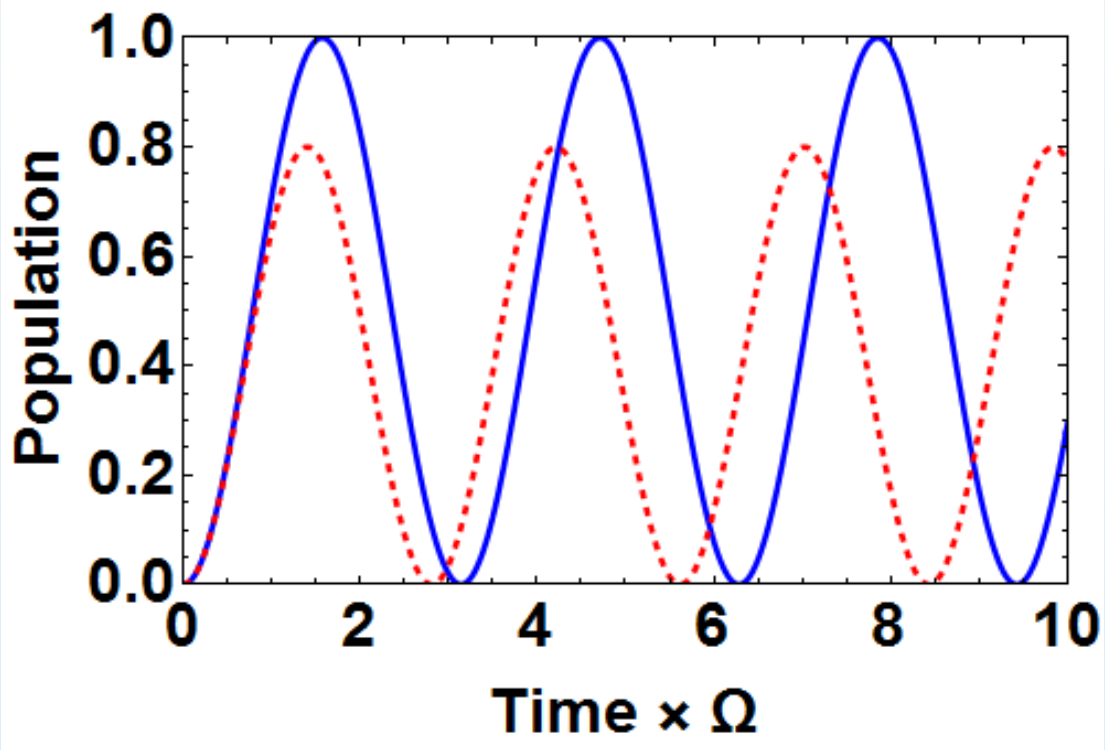


$\delta = 0$

Rabi dynamics

$$P(t) = \left|\frac{\Omega}{\Omega'}\right|^2 \sin^2(\Omega' t/2)$$

$$\Omega' = \sqrt{\Omega^2 + (\delta/2)^2}$$

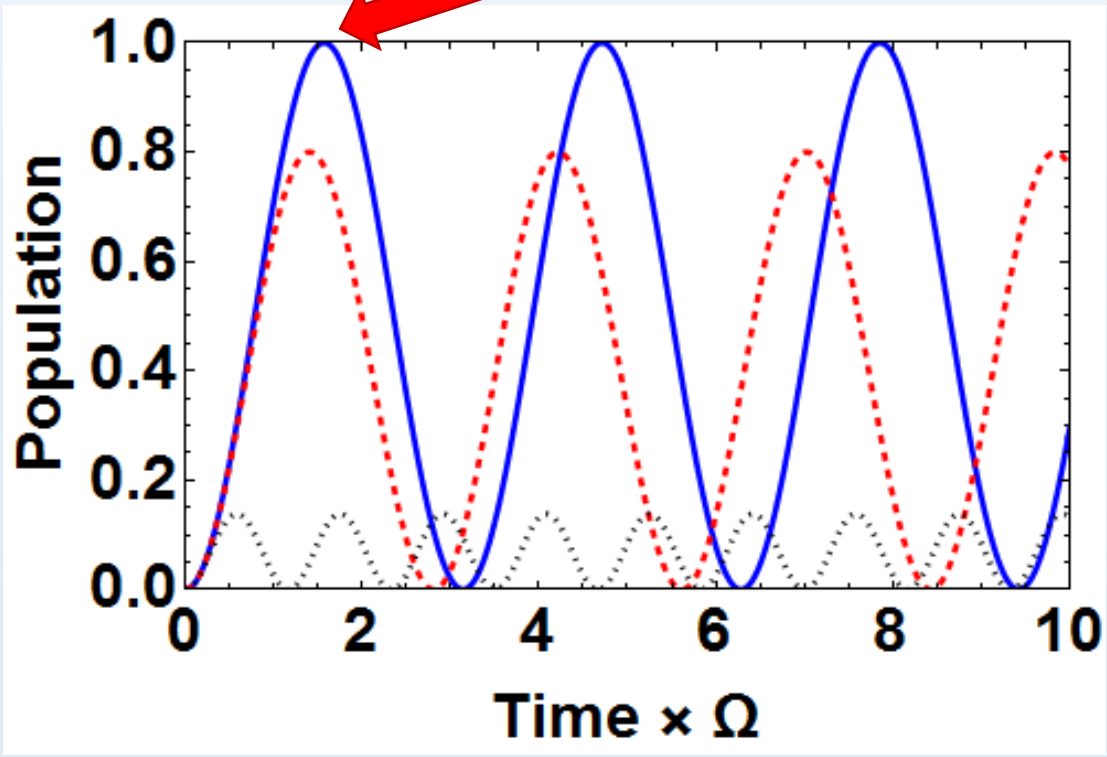


$\delta = 0$

$\delta = \Omega$

Rabi dynamics

$$t^* = \frac{\pi}{2\Omega}$$



$$P(t) = \left|\frac{\Omega}{\Omega'}\right|^2 \sin^2(\Omega' t/2)$$

$$\Omega' = \sqrt{\Omega^2 + (\delta/2)^2}$$

Let's look as a function of detuning at this "π-pulse" time

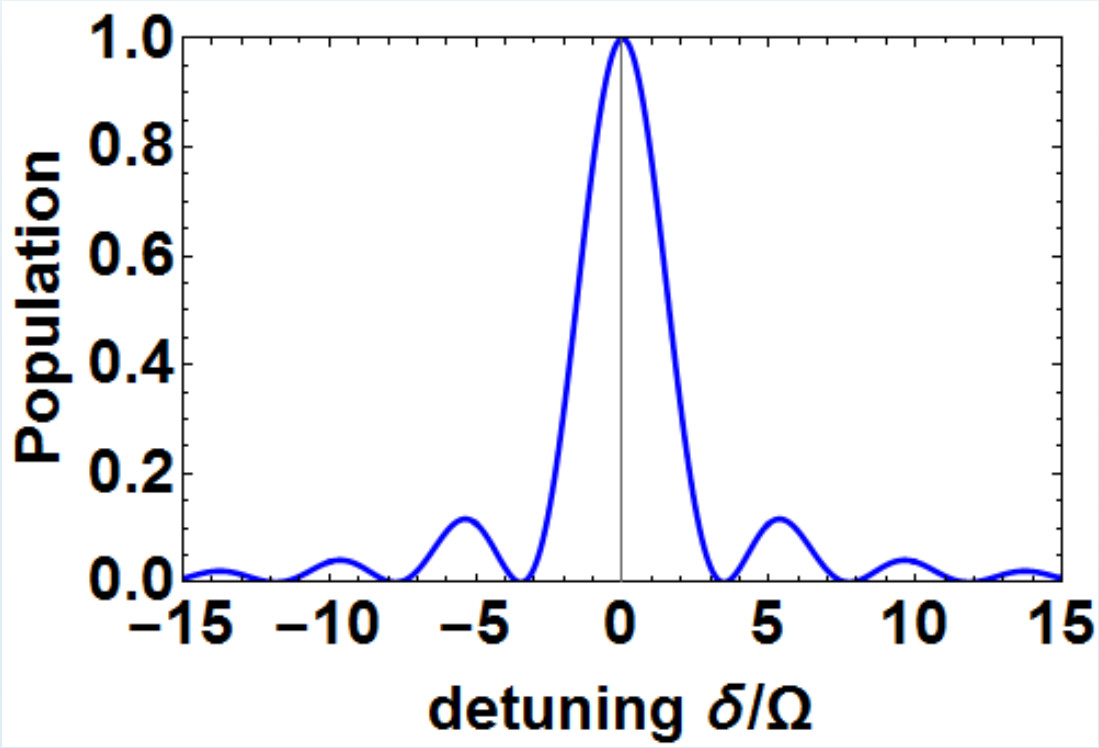
$\delta = 0$

$\delta = \Omega$

$\delta = 5\Omega$

Detuning dependence

$$t^* = \frac{\pi}{2\Omega}$$

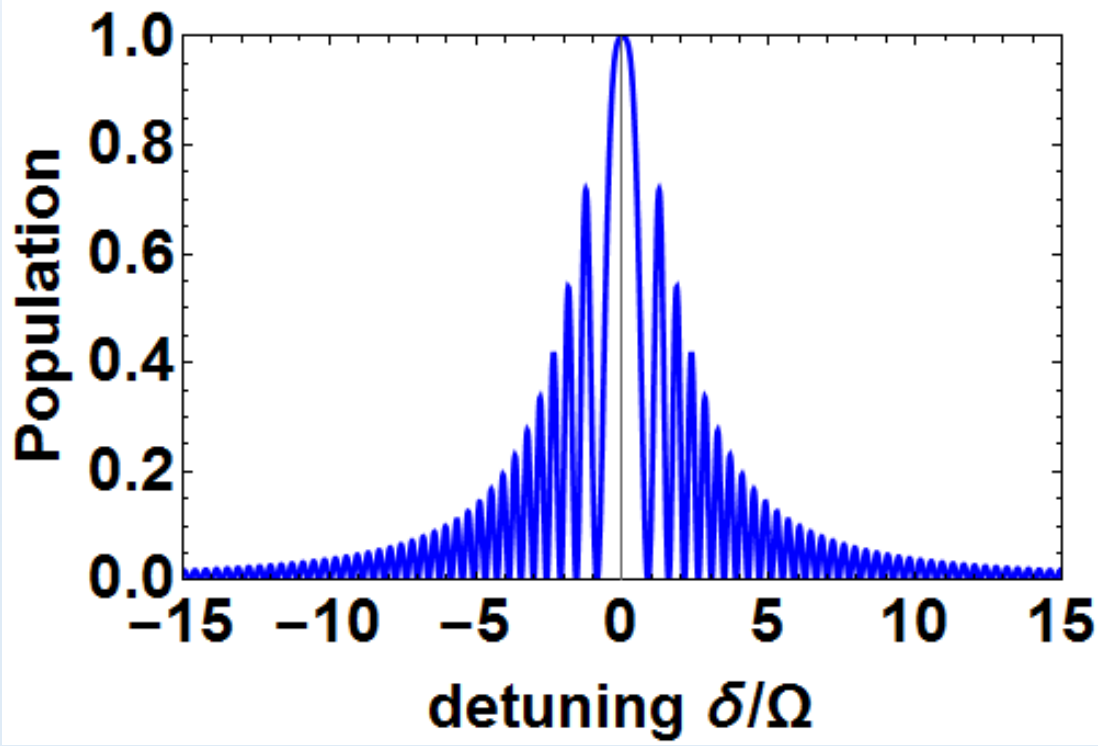


sinc^2 dependence

Fourier-broadened lineshape due to finite pulse duration

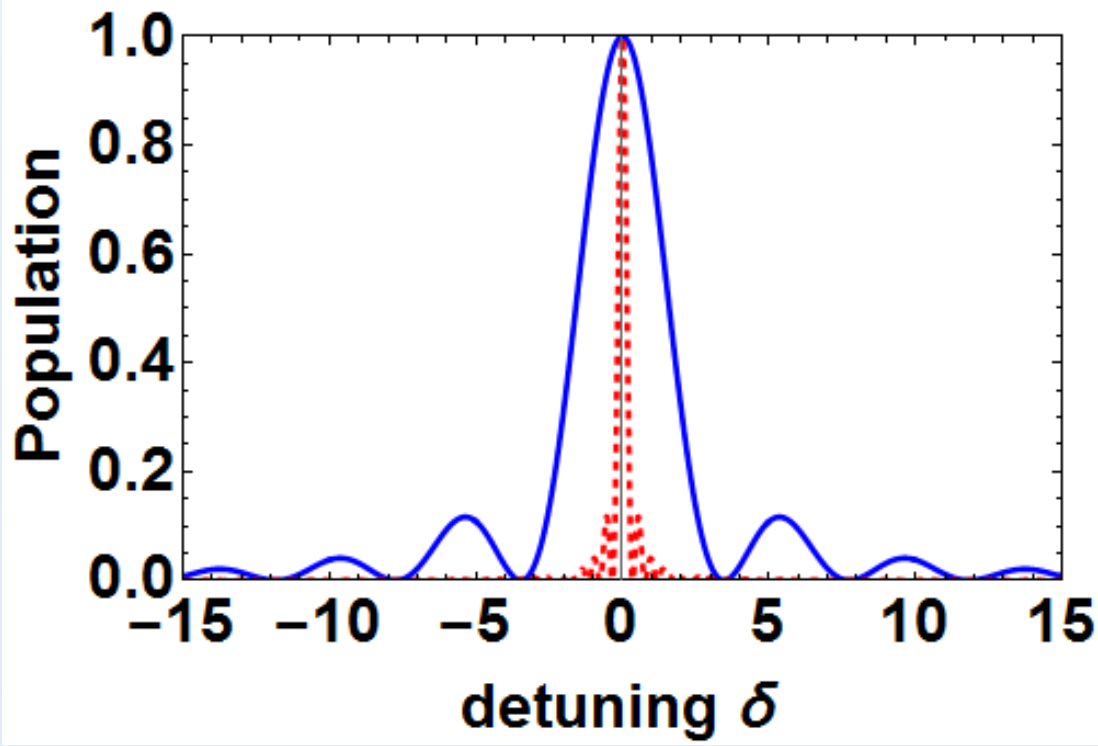
Detuning dependence

$$t^* = 5\frac{\pi}{2\Omega}$$



Detuning dependence

$$t_{1,2}^{*} = \frac{\pi}{2\Omega_{1,2}}$$



Ω_1

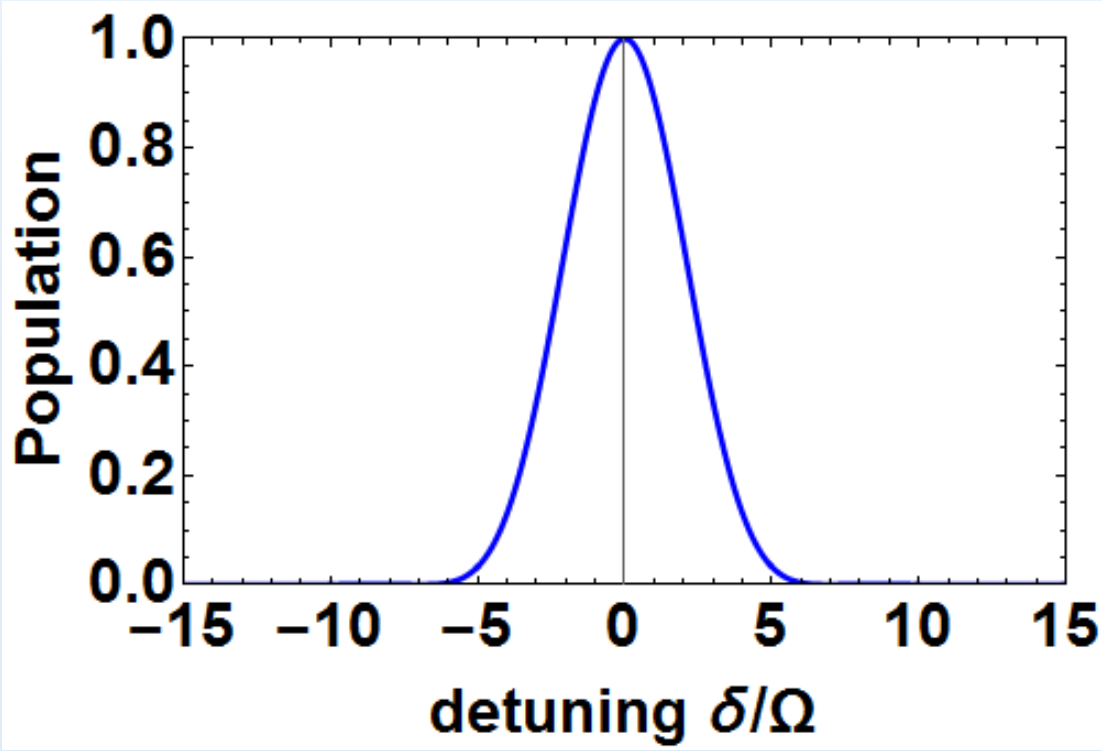
$\Omega_2 = \Omega_1 / 10$

sinc^2 dependence

Longer π-pulse gives smaller Fourier width $\Delta f \Delta t \sim 1$

Pulse-shaping

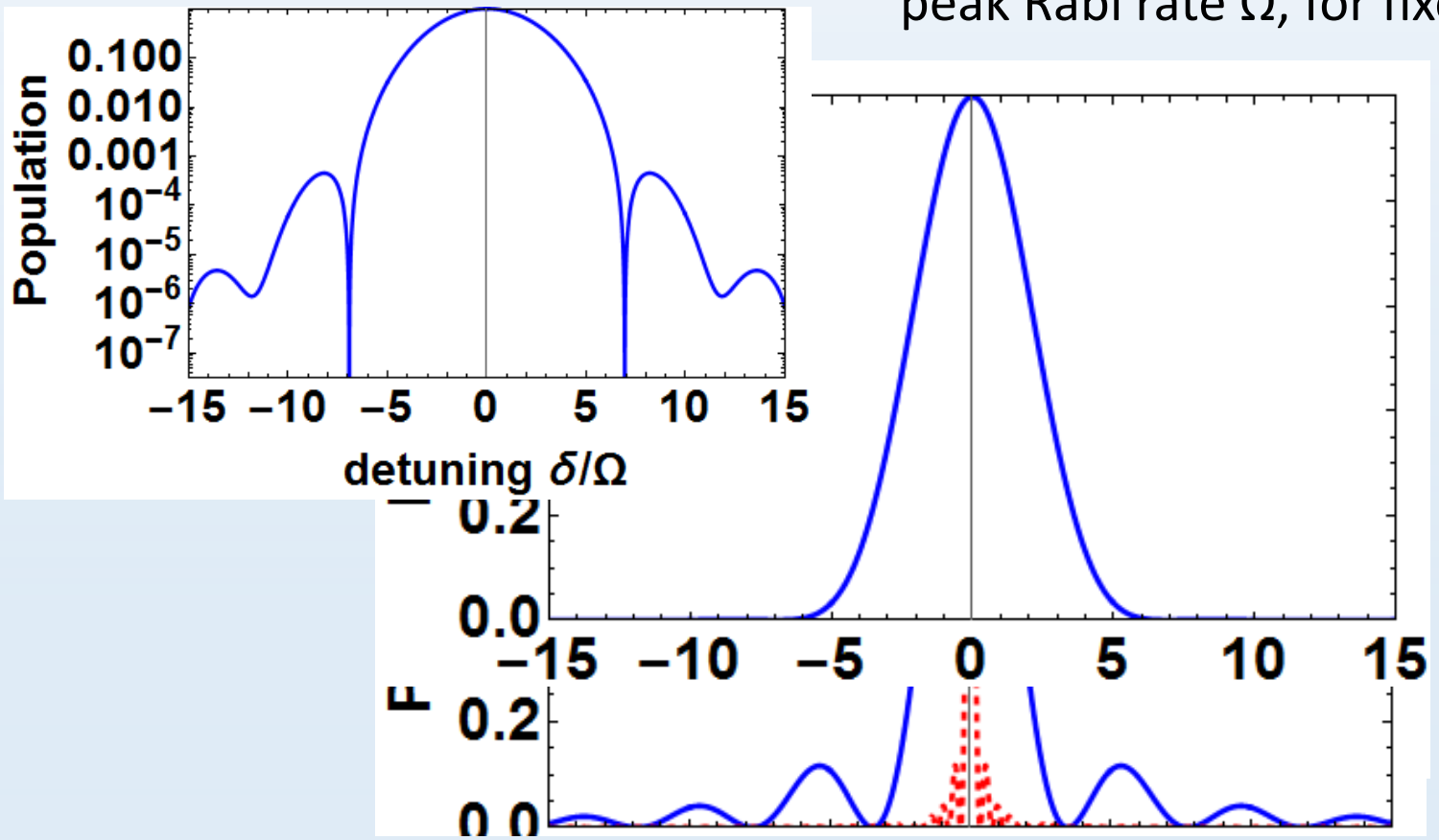
peak Rabi rate Ω, for fixed π-pulse area



Blackman pulse [like a Gaussian, but defined over finite time window]

Pulse-shaping

peak Rabi rate Ω, for fixed π-pulse area

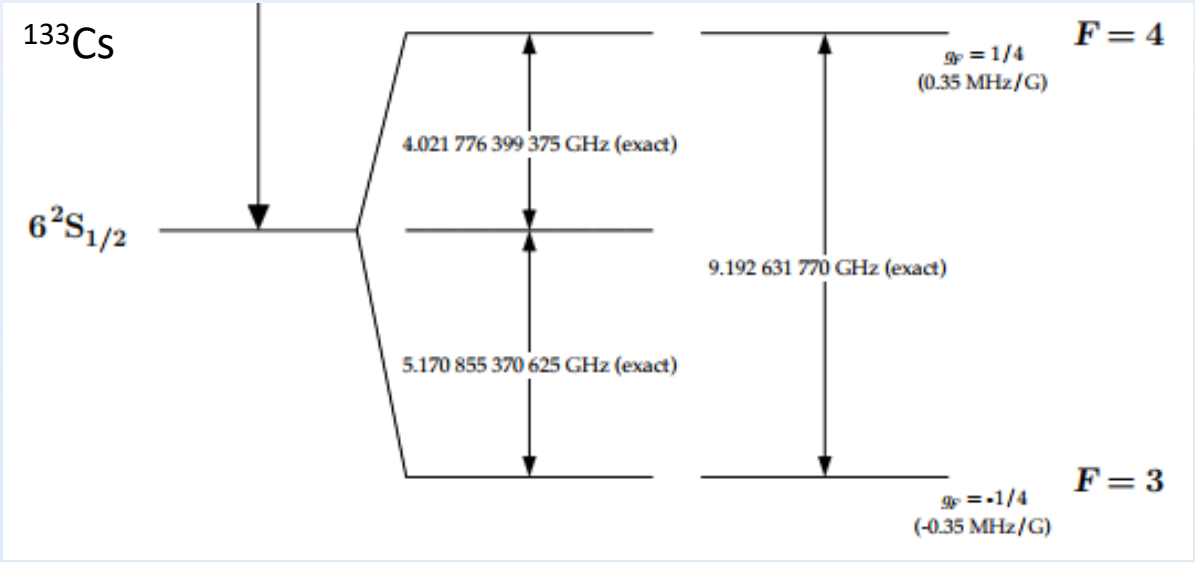


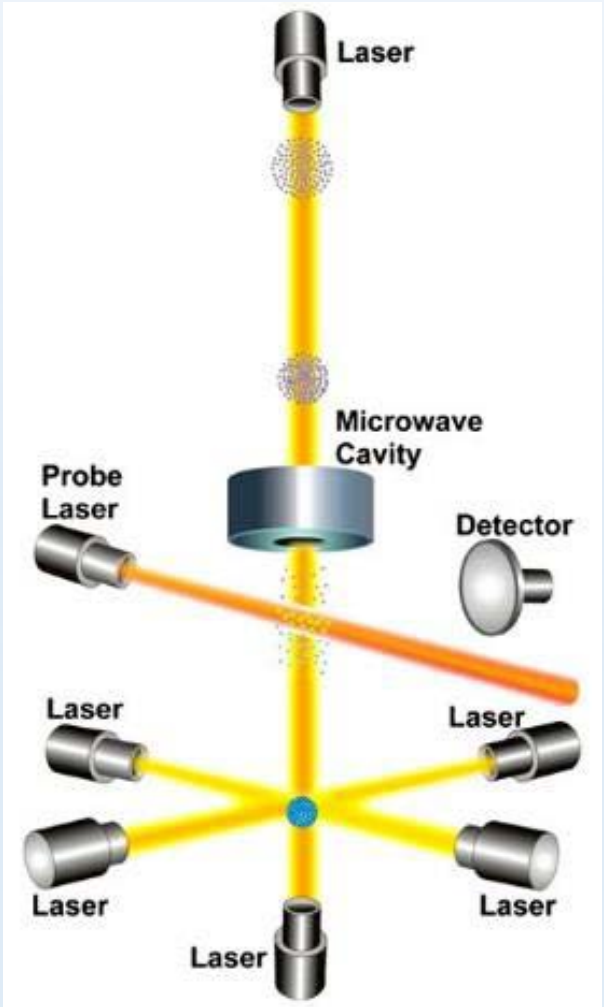
Blackman pulse [like a Gaussian, but defined over finite time window]

the cesium fountain clock

ΔE determines the SI second (and meter)

$\Delta E \propto 1/\Delta t$

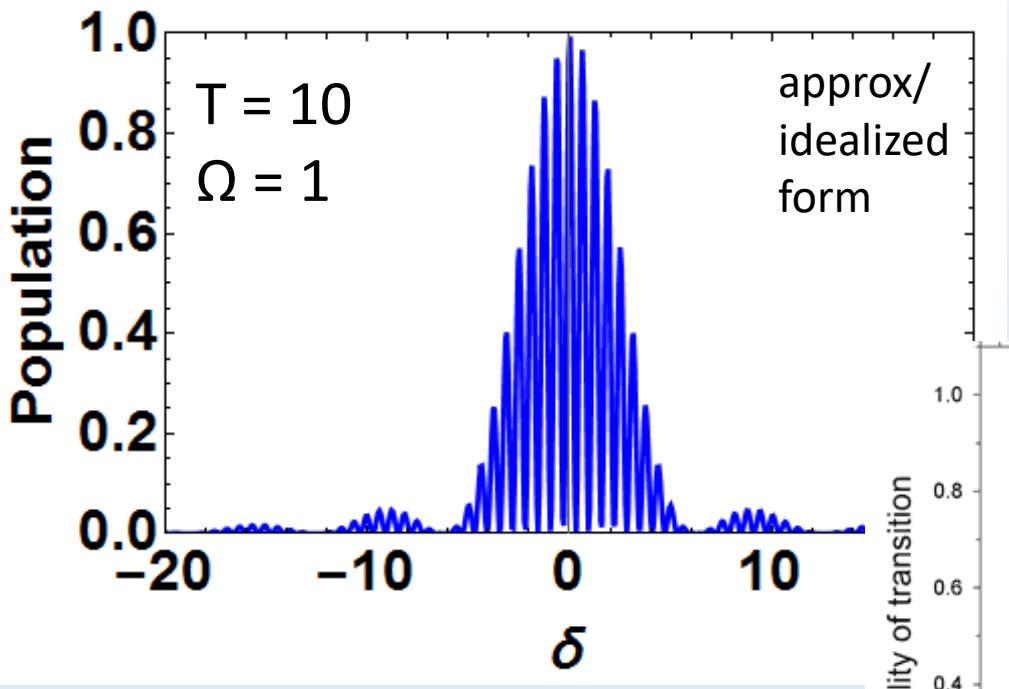


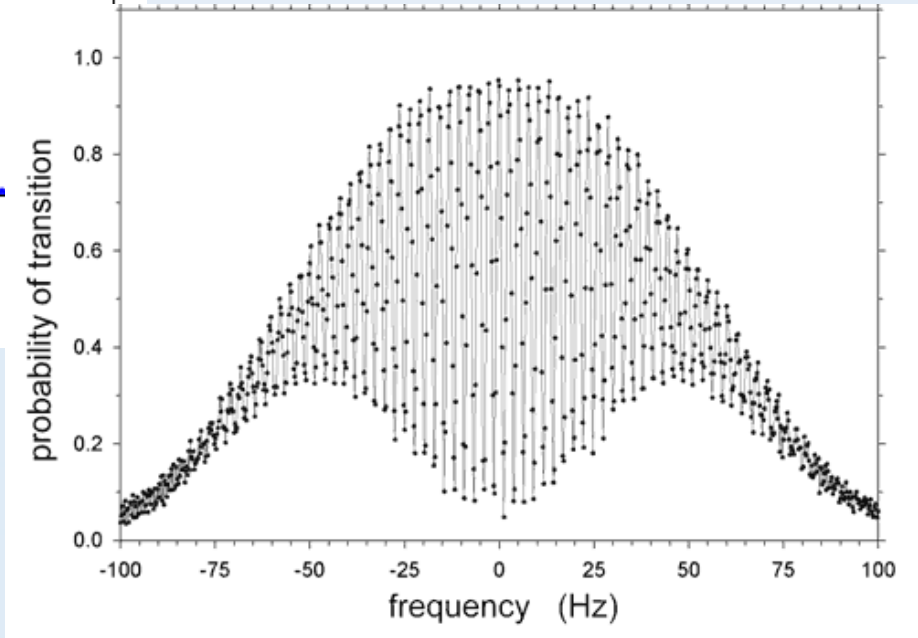


For many experiments,
long interaction time = large region of space

Hard to keep microwaves/laser (Ω) and external fields constant over large region of space

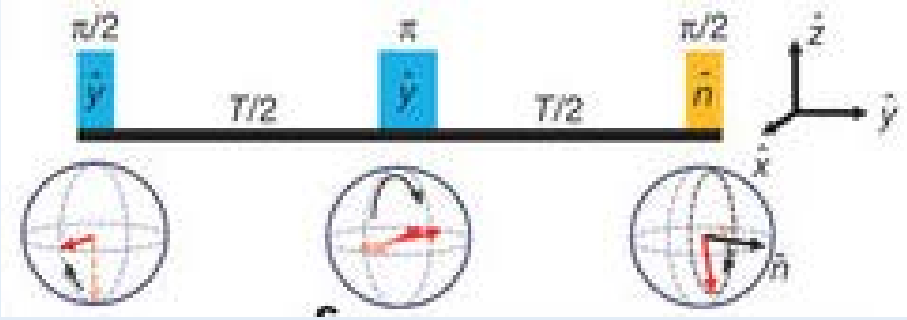
Ramsey signal

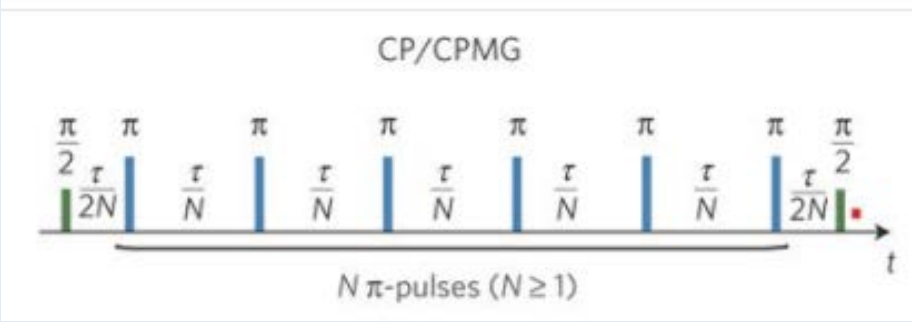




More complex procedures

Spin-echo (refocusing pulses)





More complex procedures

From

Noise spectroscopy through dynamical decoupling with a superconducting flux qubit

Jonas Bylander, Simon Gustavsson, Fei Yan, Fumiki Yoshihara, Khalil Harrabi, George Fitch, David G. Cory, Yasunobu Nakamura, Jaw-Shen Tsai & William D. Oliver

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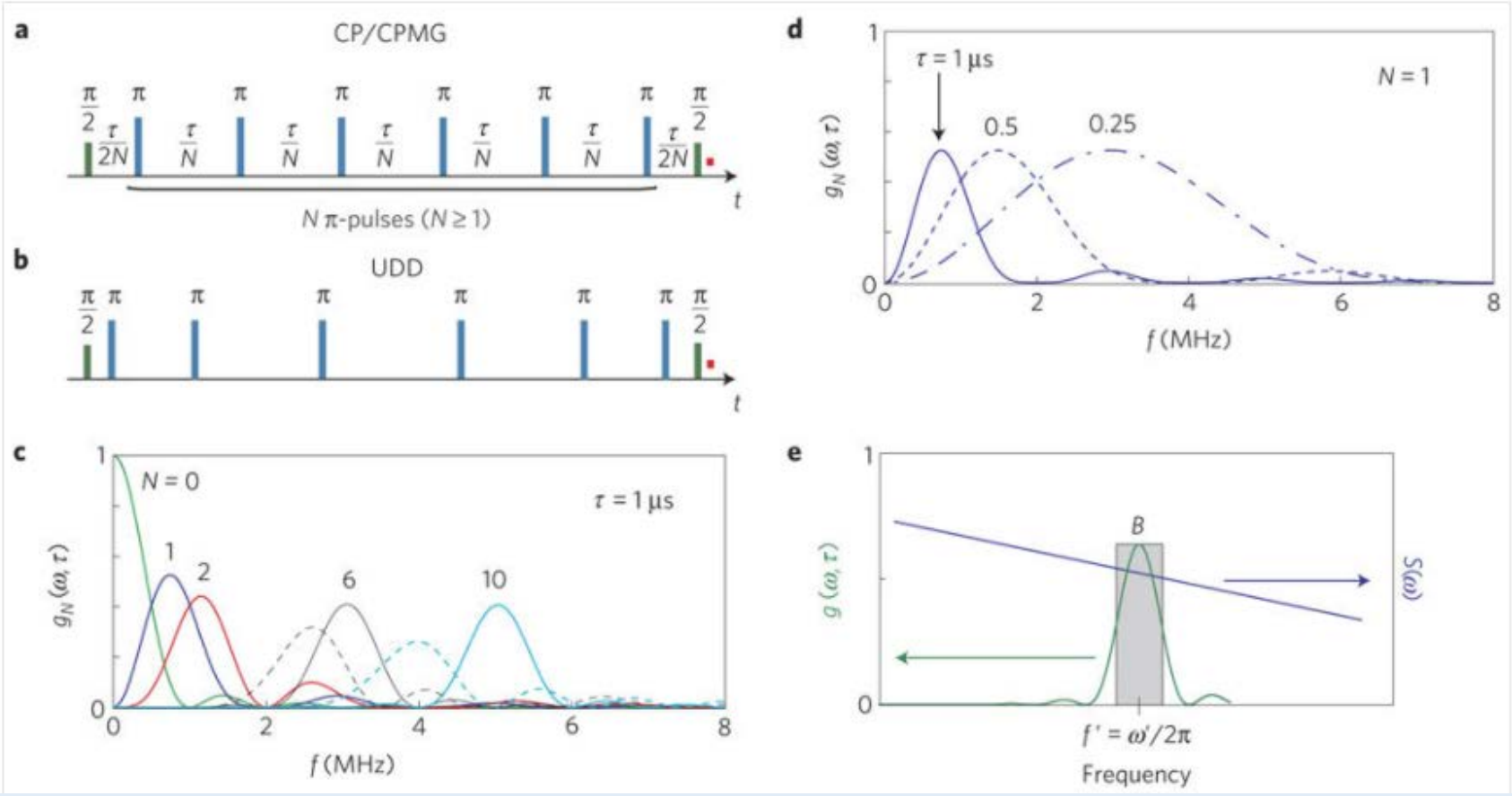

More complex procedures

WAHUHA