Status of the Cosmic Axion Spin Precession Experiment (CASPEr)

NMR Meets Dark Matter

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for the CASPEr collaboration

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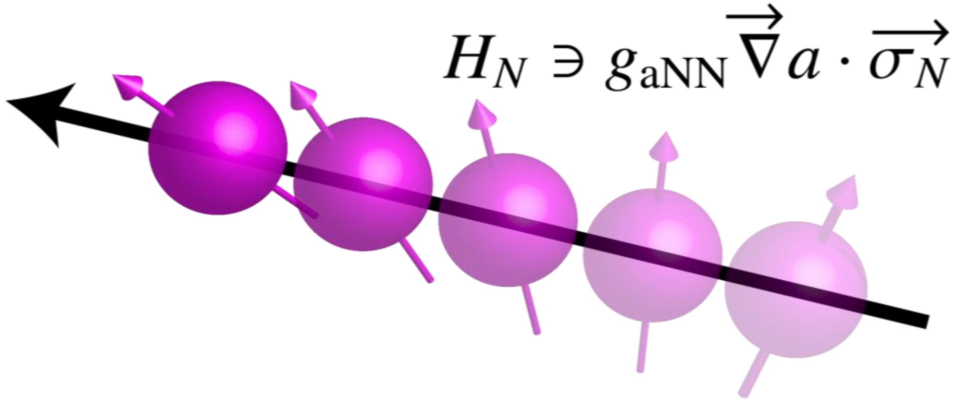
JG|U

Axion – spin couplings



CASPEr – Wind:

- ALP-nuclear spin couplings

→ same as magnetic field coupling to spins

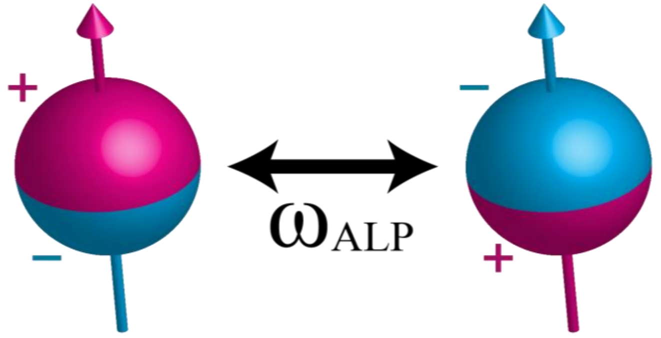
→ induces precession

$$\boldsymbol{B}_{ALP} \approx g_{aNN}\sqrt{2\rho_{DM}}\cos(m_a t)\boldsymbol{v}_{ALP}$$

CASPEr - Electric:

- ALP induce oscillating nuclear electric dipole moment

$$\boldsymbol{d}(t) \cdot \boldsymbol{E} \leftrightarrow \boldsymbol{\mu} \cdot \boldsymbol{B}(t)$$



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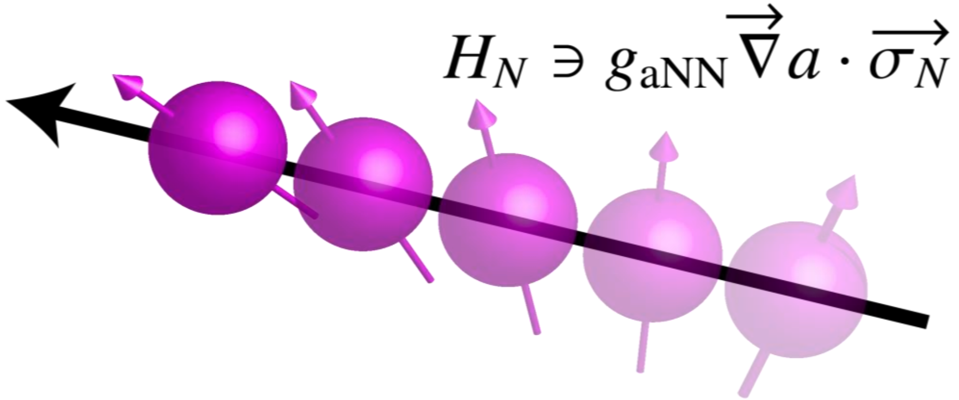

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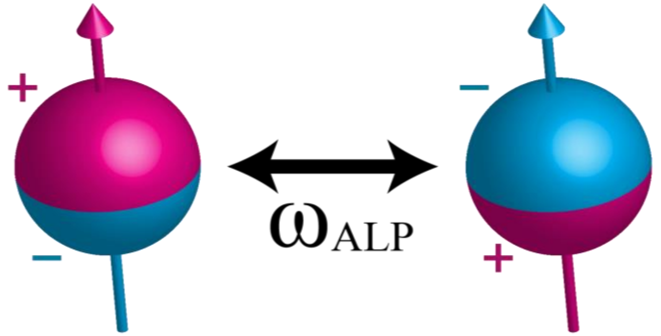

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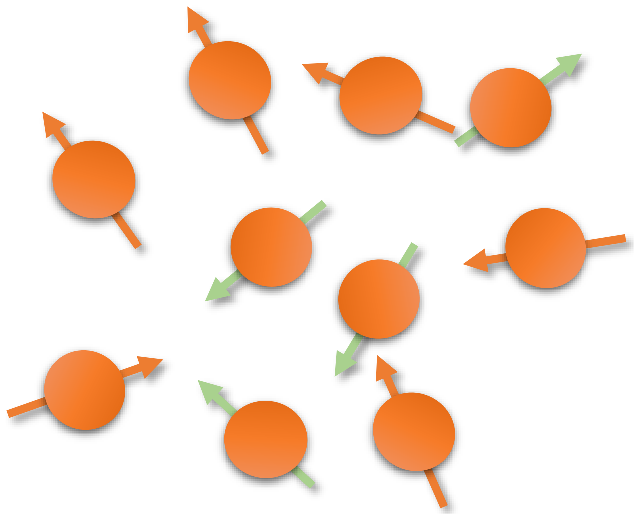
CASPEr looks for any kind of "wavy" dark matter that couples to nuclear spins

Nuclear Magnetic Resonance

1. Nuclei with $\mathbf{I} \neq \mathbf{0}$
2. In a magnetic field → Spins precess

$$\omega_L = \gamma B_o$$

3. General magnetization $\vec{M}$ (**polarization**)
4. Apply $\vec{B}_1$ **oscillating transverse** field
5. When $\boldsymbol{\omega_1} = \boldsymbol{\omega_L}$ → spins are tilted
6. We get **transverse magnetization**



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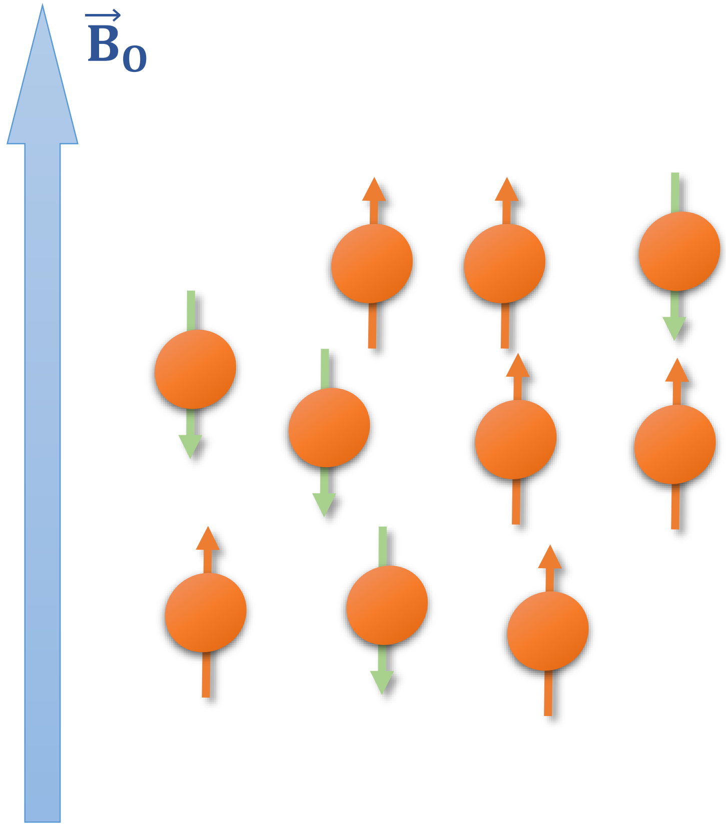

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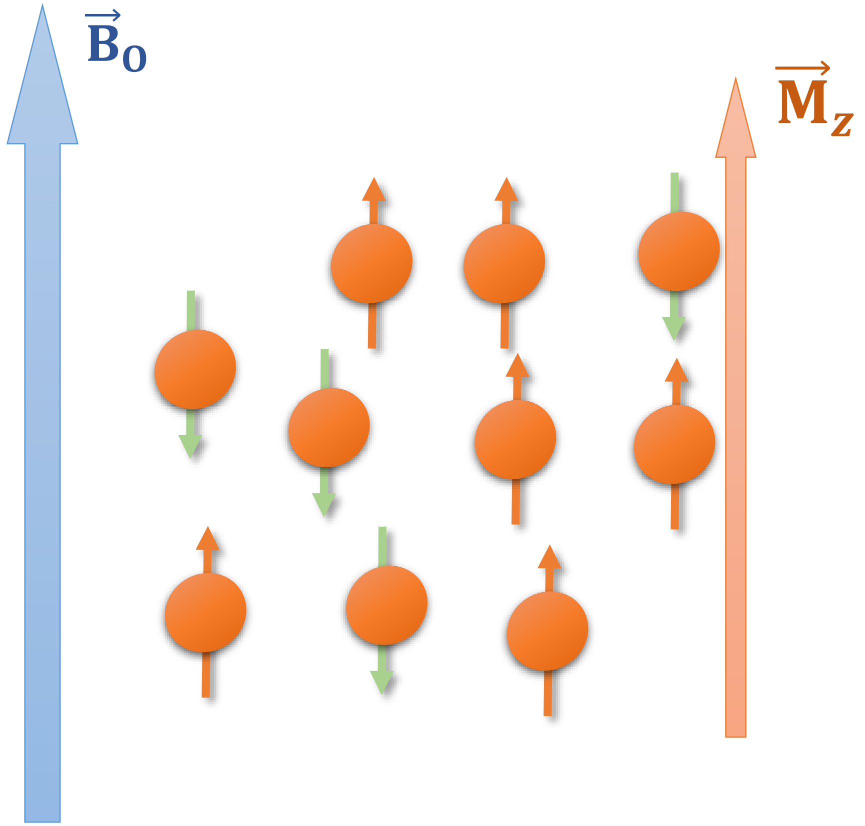

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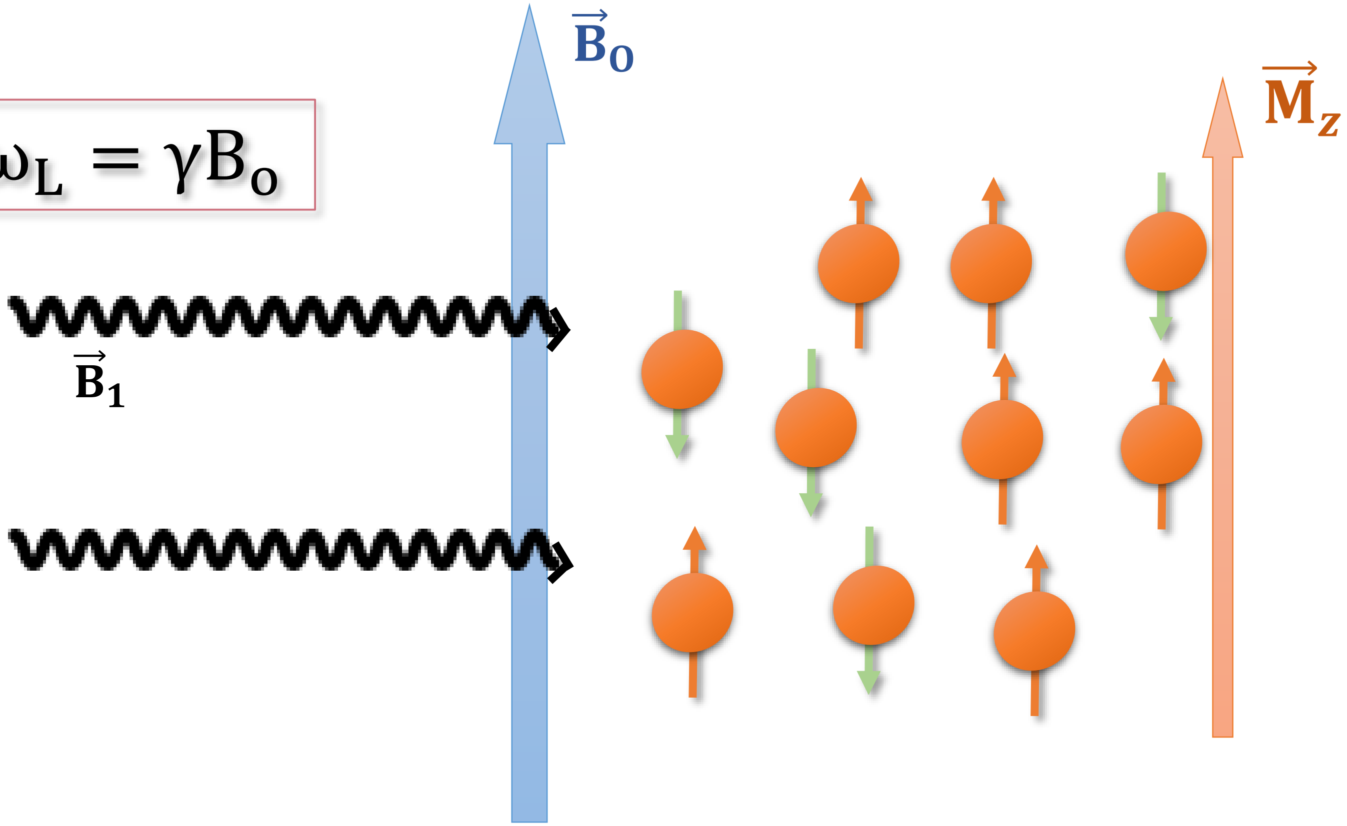

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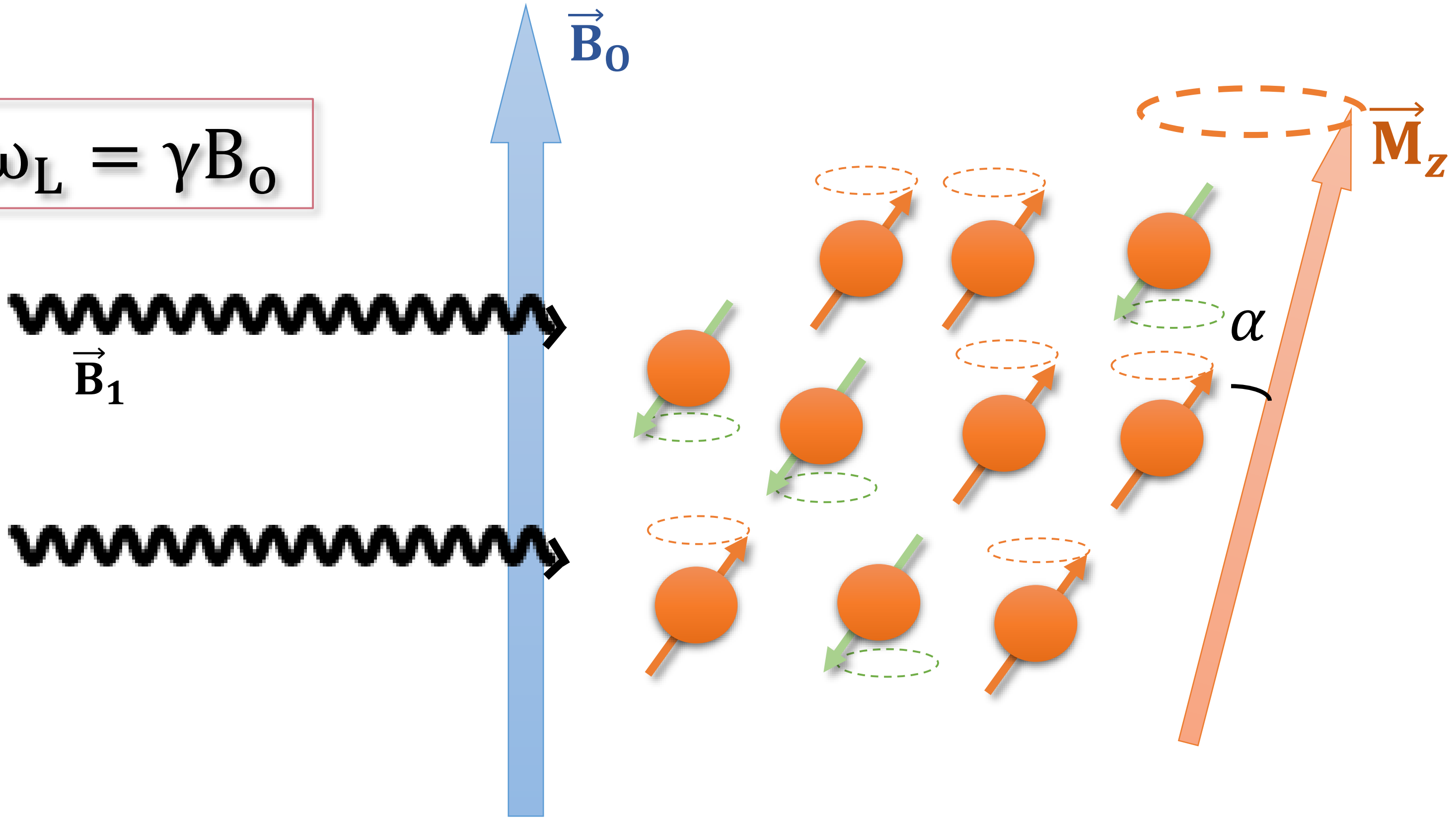

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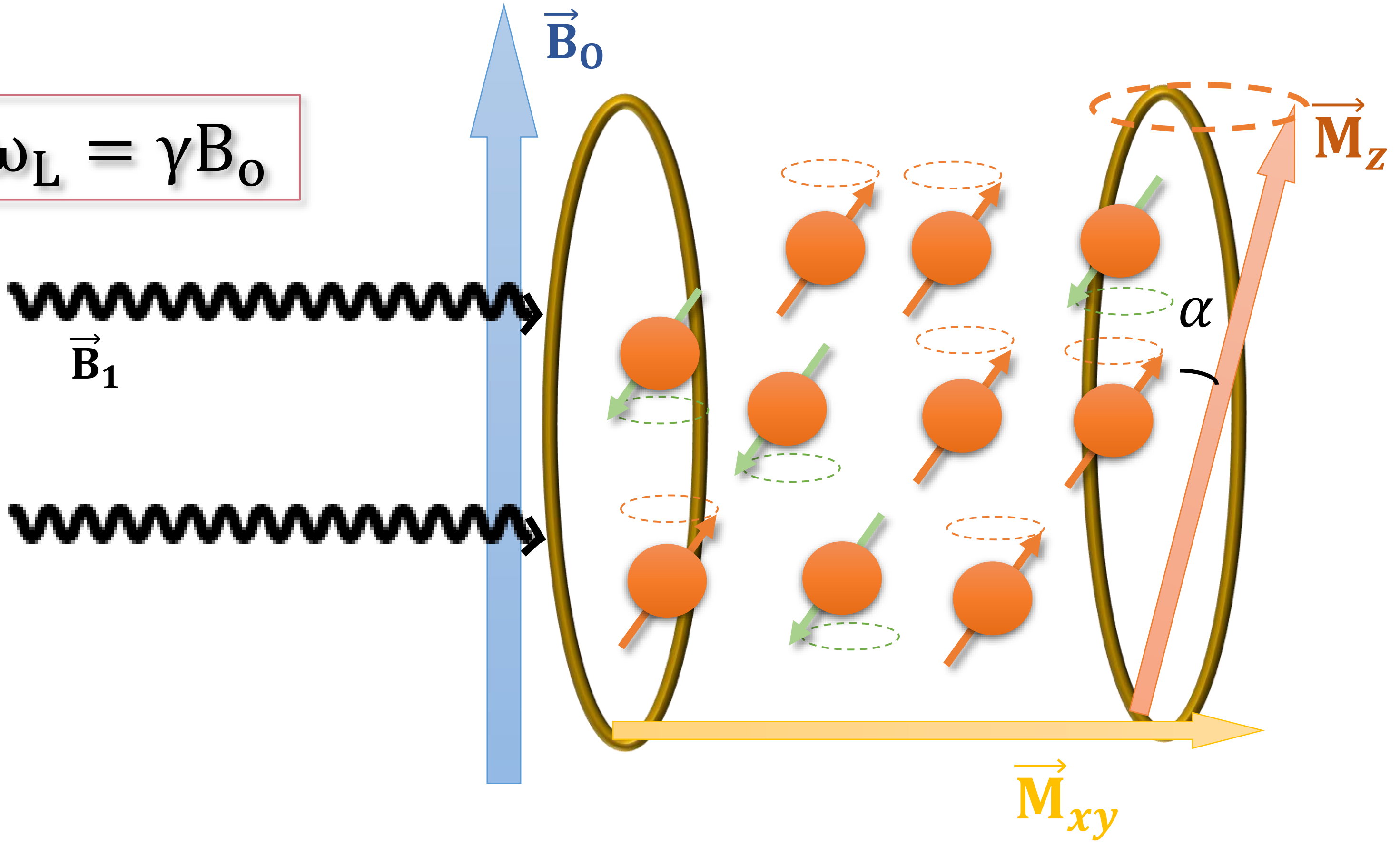

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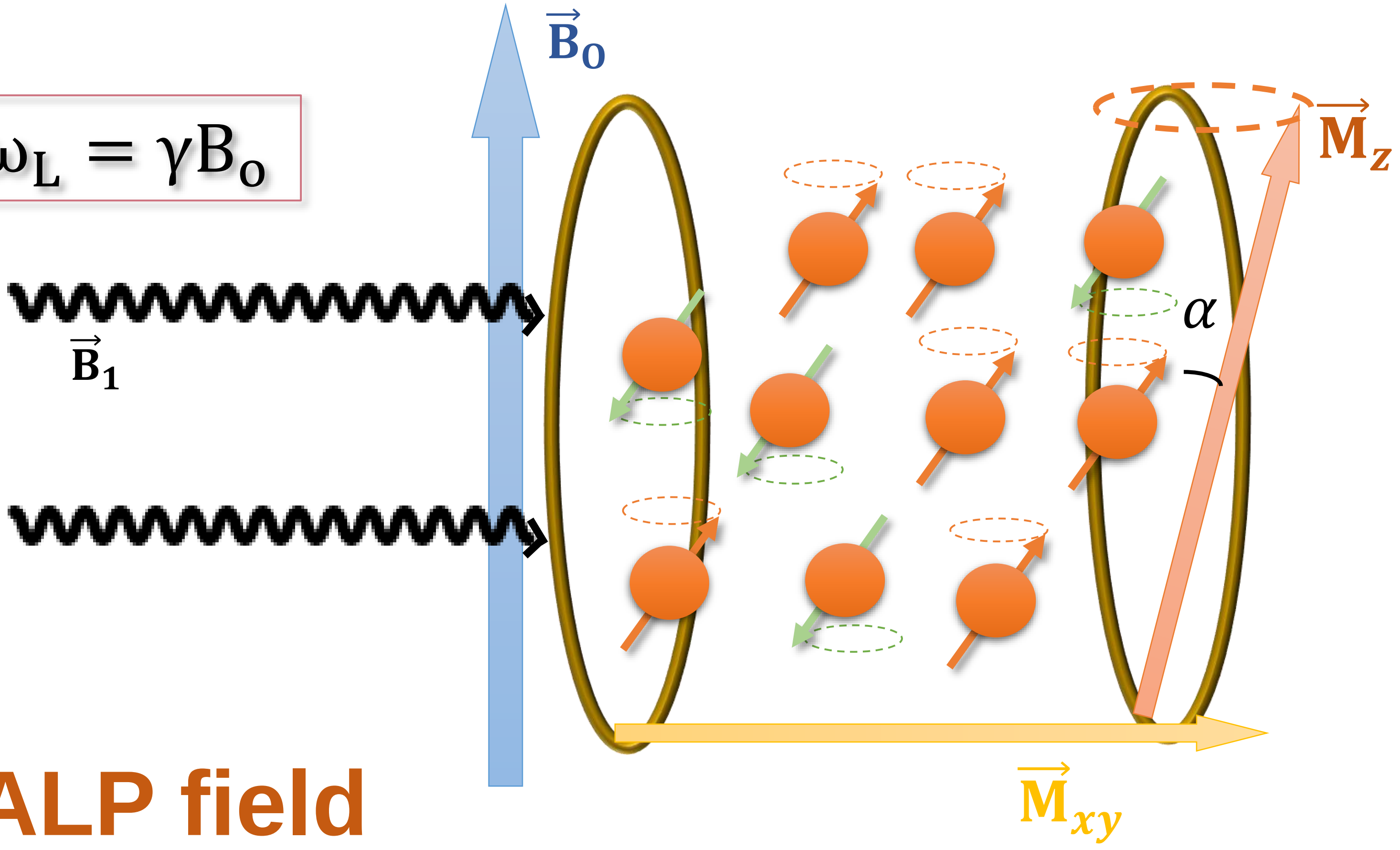
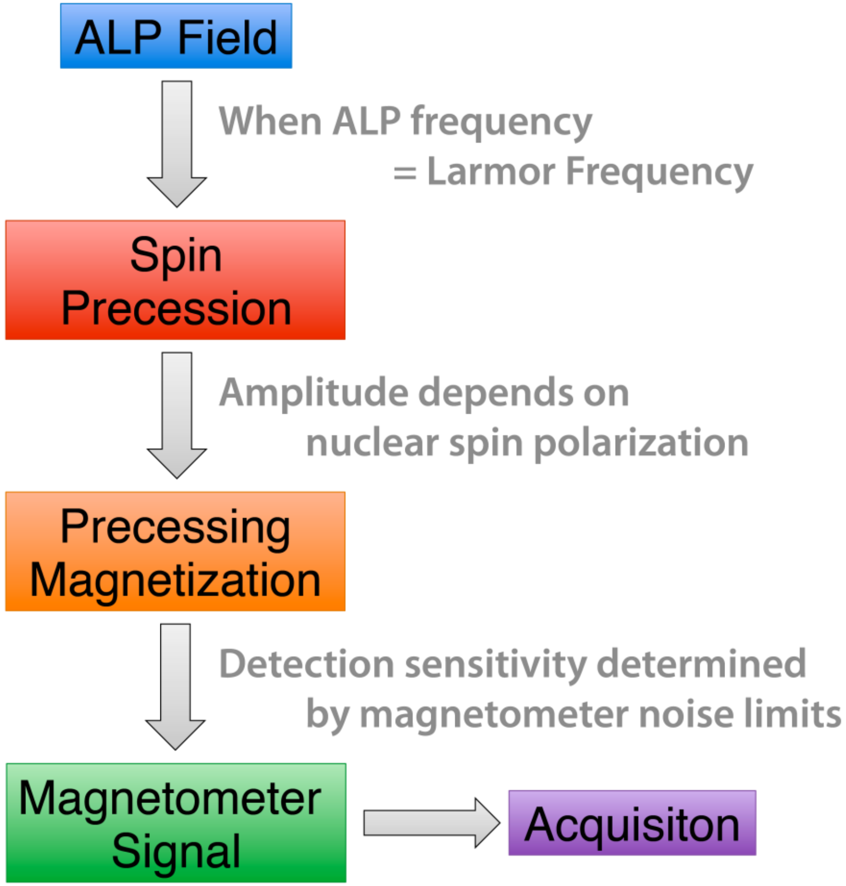
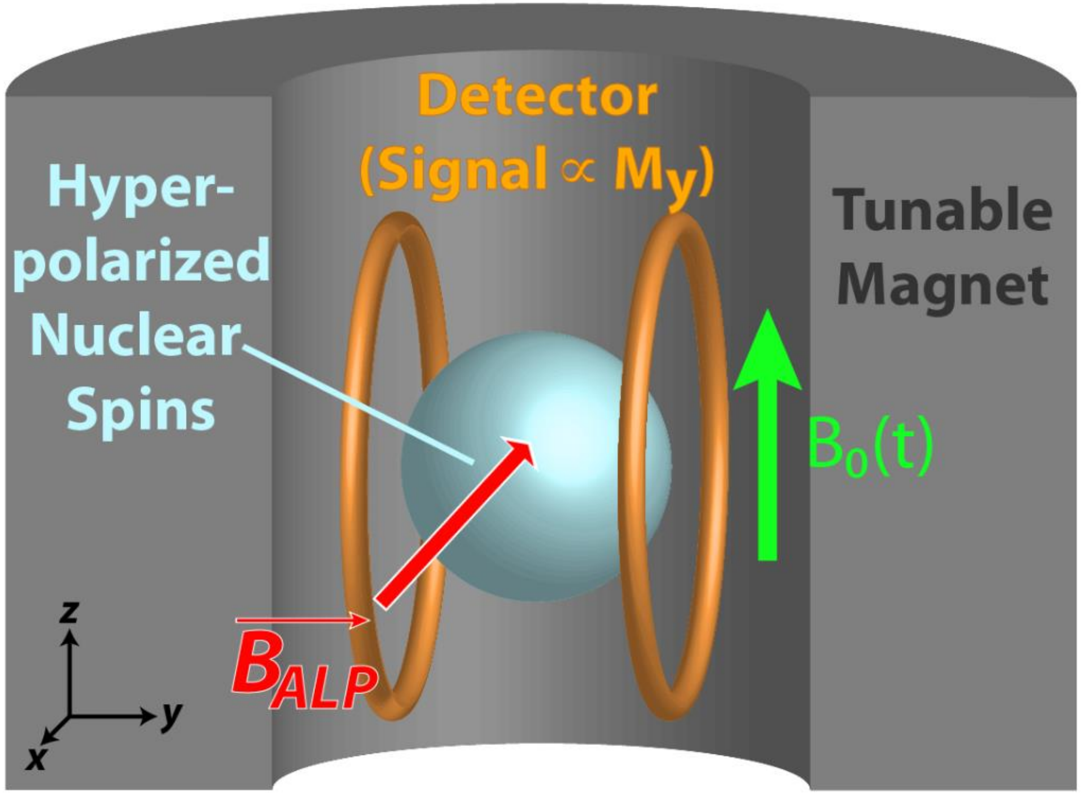


CASPEr → B_1 is the ALP field

CASPEr detection scheme





1. **CASPEr ZULF →** $B_o \leq 10^{-4}$ T
2. **CASPEr -Wind Low Field →** $10^{-4}\text{T} \leq B_o \leq 10^{-1}$ T
3. **CASPEr –Wind High Field→** $0.1\ \text{T} \leq B_o \leq 14$ T

CASPEr - Wind

$$M(t) \approx np\mu\left(g_{\mathrm{aNN}}\sqrt{2\rho_{\mathrm{DM}}}v\right)\frac{\sin\left[(2\mu B_0 - m_a)\,t\right]}{2\mu B_0 - m_a}\sin(2\mu B_0 t)$$

Signal is REALLY small!

We need to maximize:

- Number density (n)
- Polarization (p)
- Nuclear magnetic moment (μ)
- Sensitivity

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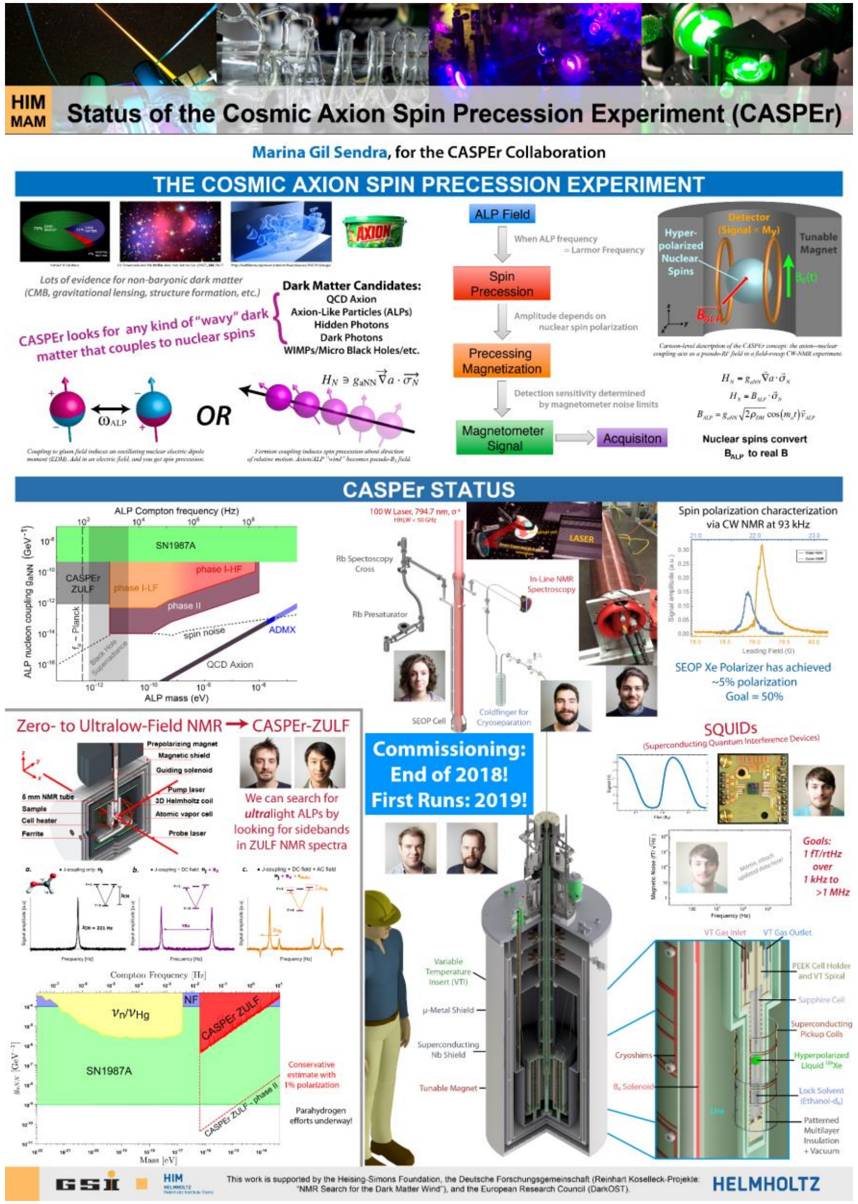
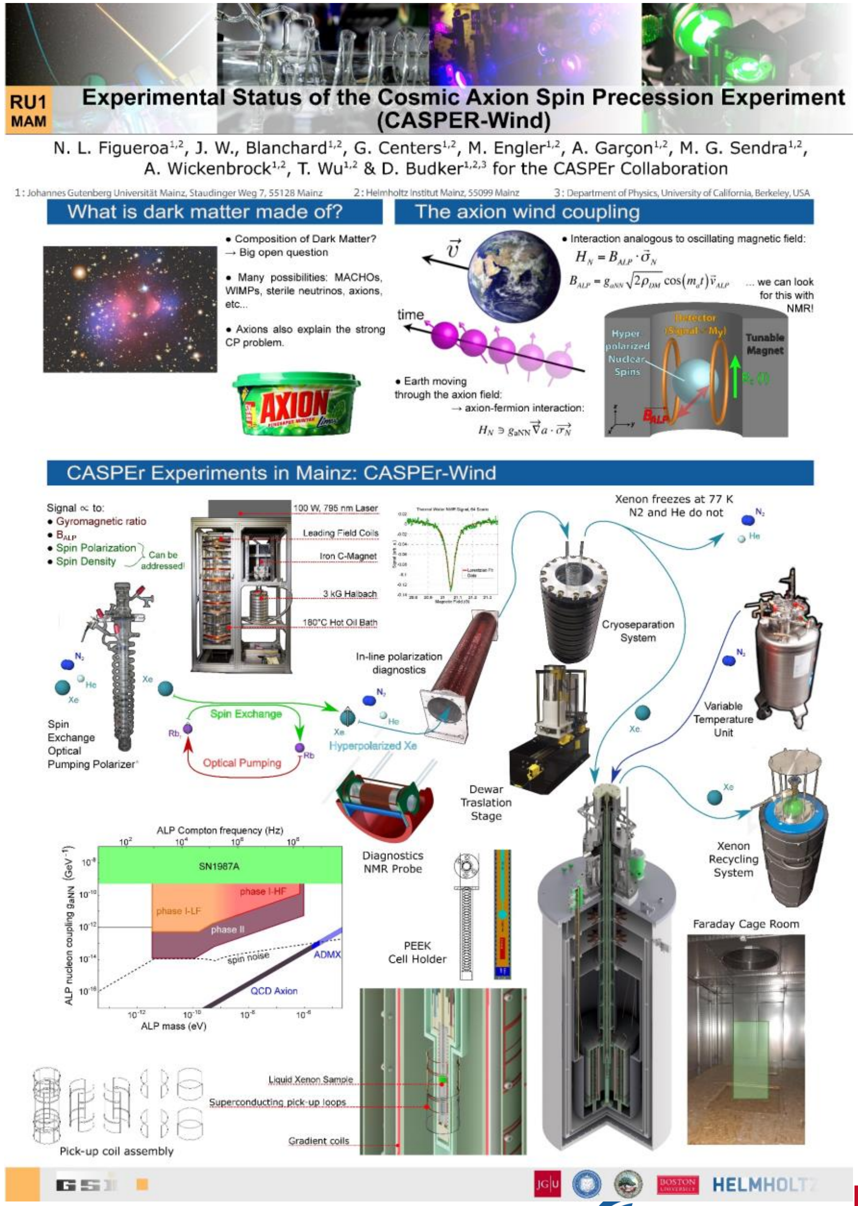
Hyperpolarized liquid ^{129} Xe

Cryogenic probe, SQUIDs, etc

LATER! → Gary Centers & Nataniel Figueroa





THANKS!