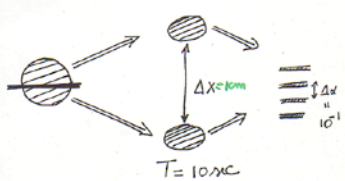
PERSONAL PERSPECTIVES ON BEC - PHYSICS

EDDY TIMMERMANS, T-4

AMO-TECHNOLOGY → LOW TEMP. MANY-BODY →
DILUTE GAS → ACCESSIBILITY → PHASE COHERENCE

* SUPERFLUID-LIKE (EQ.) PRESERVATION PHASE
* LASER-LIKE SPATIAL INTERFERENCE



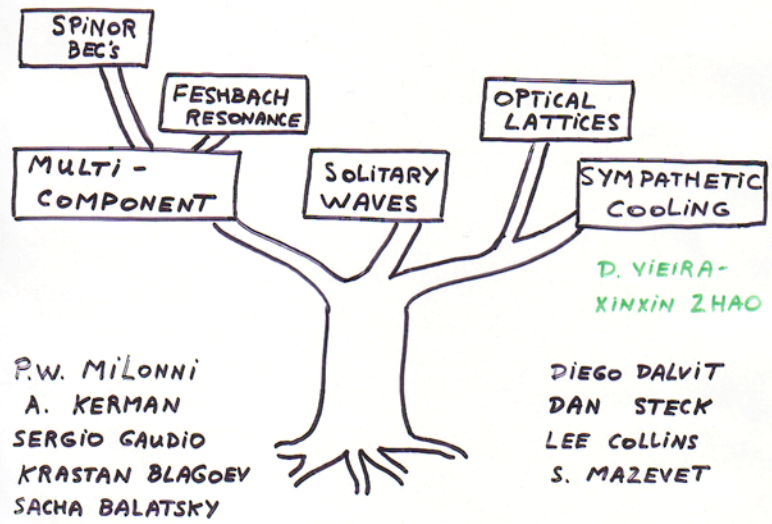
$$g = \frac{\Delta\alpha\,\hbar}{M\,\Delta X\,T}$$

$$\overset{(A=87)}{\sim} \frac{10^{-12}}{(\Delta X/m)}\ m/sec^2$$

$$\frac{\Delta g}{g} \sim 10^{-14}$$

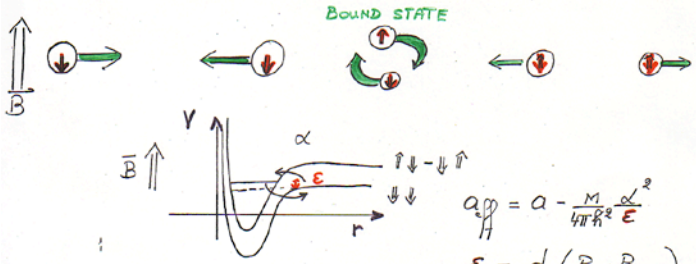
* FUNDAMENTAL / APPLICATIONS
* MULTI-DISCIPLINARY

BEC-RESEARCH (THEORY - E.T.)



MAGNETICALLY CONTROLLED

FESHBACH RESONANCE



$$a_{eff} = a - \frac{M}{4\pi\hbar^2}\frac{\alpha^2}{\varepsilon}$$

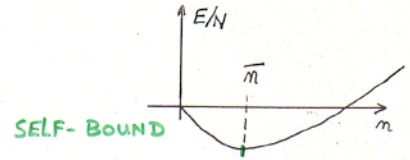
$$\varepsilon = d\,(B - B_{res})$$

KNOB

MUTUALLY COHERENT ATOMIC & MOLECULAR SUPERFLUIDS

- POPULATION OSCILLATIONS (JOSEPHSON-LIKE) → OBSERVED (JILA)
- SELF-DETERMINED DENSITY (LIQUID-LIKE)

NEAR RESONANCE



SELF-BOUND

$$n_s \simeq \bar{n} = \frac{(d/\mu_B)\,(\Delta/G)}{(a/1nm)} \times A \times 1.11 \times 10^{16}\ cm^{-3}$$

PROBLEM
- * n_s TOO HIGH
- * TOO MANY MOLECULES

SOLUTION

NEAR $a_{eff} = 0$ $\quad B = B_0 \quad \delta B = B - B_0$

$$n_s \sim \left(\frac{\delta B}{\Delta}\right)\left(\frac{a_{atom-mol.}}{a}\right)\bar{n}$$

PAY-OFF

SELF-CONFINED BEC
TRANSPORTING BEC'S
NO FOCUSSING NEEDED

RESONANT ENTANGLEMENT OF NEUTRAL ATOMS

E. TIMMERMANS
D. JAMES
EXP: XINXIN ZHAO - D. VIEIRA

A) NEUTRAL ATOMS / Q.I.P. HARDWARE

Q-BIT: ATOM IN HYPERFINE STATES
REGISTER: ATOMS TRAPPED IN OPTICAL LATTICE

QUANTUM OPERATIONS

SINGLE Q-BIT: COHERENT 2-PHOTON COUPLING
GATE : STATE-DEPENDENT 2-PARTICLE INT.

CONTROLLED Z

a	b		
$\|0\rangle$	$\|0\rangle \rightarrow$	$\|0\rangle\|0\rangle$	
$\|0\rangle$	$\|1\rangle \rightarrow$	$\|0\rangle\|1\rangle$	
$\|1\rangle$	$\|0\rangle \rightarrow$	$\|1\rangle\|0\rangle$	
$\|1\rangle$	$\|1\rangle \rightarrow$	$-\|1\rangle\|1\rangle$	

- NEUTRAL ATOM COLLISIONS
- INDUCED INTERACTIONS

SUITABLE? IN PRINCIPLE 5/5

ADV: LONG DECOHERENCE TIMES / FLEXIBILITY CONTROL

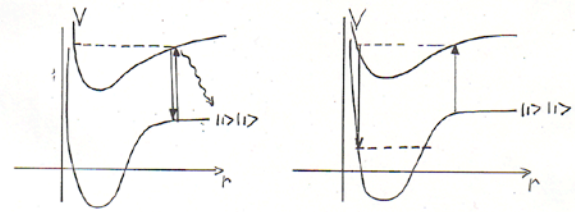
DISADV: SLOW

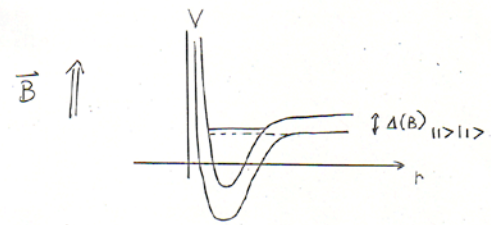
B) ENTANGLEMENT

INTERACTIONS : CHOICES

I) POTENTIAL VS RESONANT → SP.-DEP.
II) PERMANENT VS INDUCED → STRONGER + CONTROL
III) LONG VS SHORT - RANGED
↳ NO DIFFICULTIES 'ISOLATING' INTERACTIONS

"OUR SPIN" : MOLECULAR RESONANCE



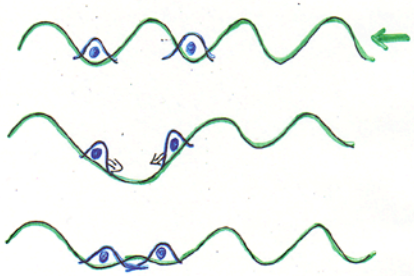


$a_{eff} > a$ $\quad \Delta\gamma_{|1\rangle|1\rangle} = \frac{4\pi\hbar}{M}\int |\phi_a(\bar{x})|^2 |\phi_b(\bar{x})|^2 d^3\bar{x}\, a_{eff}$

SHORT-RANGE ⇒ OVERLAP

C) CENTER OF MASS DYNAMICS

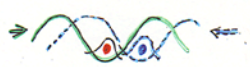
* a/b INDISTING.



a/b DIFFERENT

* SAME ISOTOPE
  DIFFERENT HYPERF.

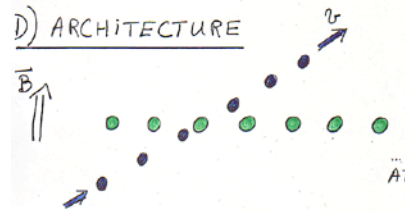
POLARIZATION OPTICAL LATTICE
LIGHT ⇒ OVERLAP



* DIFFERENT ISOTOPE
  ⇓
  DIFFERENT OPTICAL LATTICES

MOVE WELLS "THROUGH" EACH OTHER

D) ARCHITECTURE



o a-atoms Rb
• b-atoms Li

ATOMS IN GROUNDSTATE OF WELLS (EXTENT L)

B : NEAR RESONANCE

$$a_{eff}|1\rangle|1\rangle > a$$

$$v_\pi \approx 2\nu\, a_{eff}$$

AVOID EXCITATION TO HIGHER HARMONIC OSC. STATES

$$a_{eff} < L$$

GATE-RATE t_c^{-1} (t_c: time of overlap) $\quad t_c^{-1} \ll 2\nu$ LIMIT

$\nu \sim 1\,kHz - MHz$

FIDELITY - DEC. - FINITE TEMP...