PSAS 2008

Experimental measurement of the Helium 2^3P_1 - 1^1S_0 transition rate

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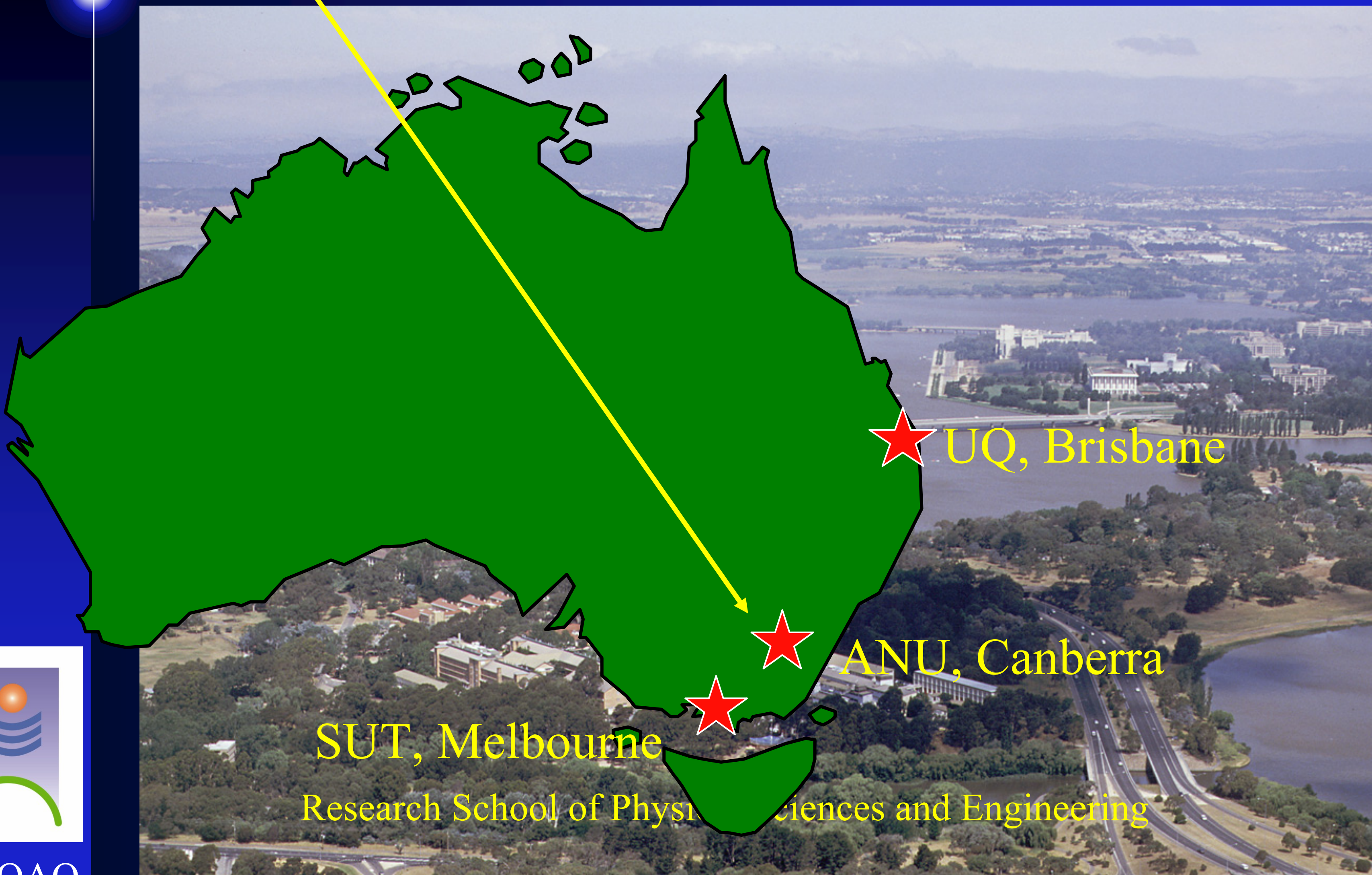

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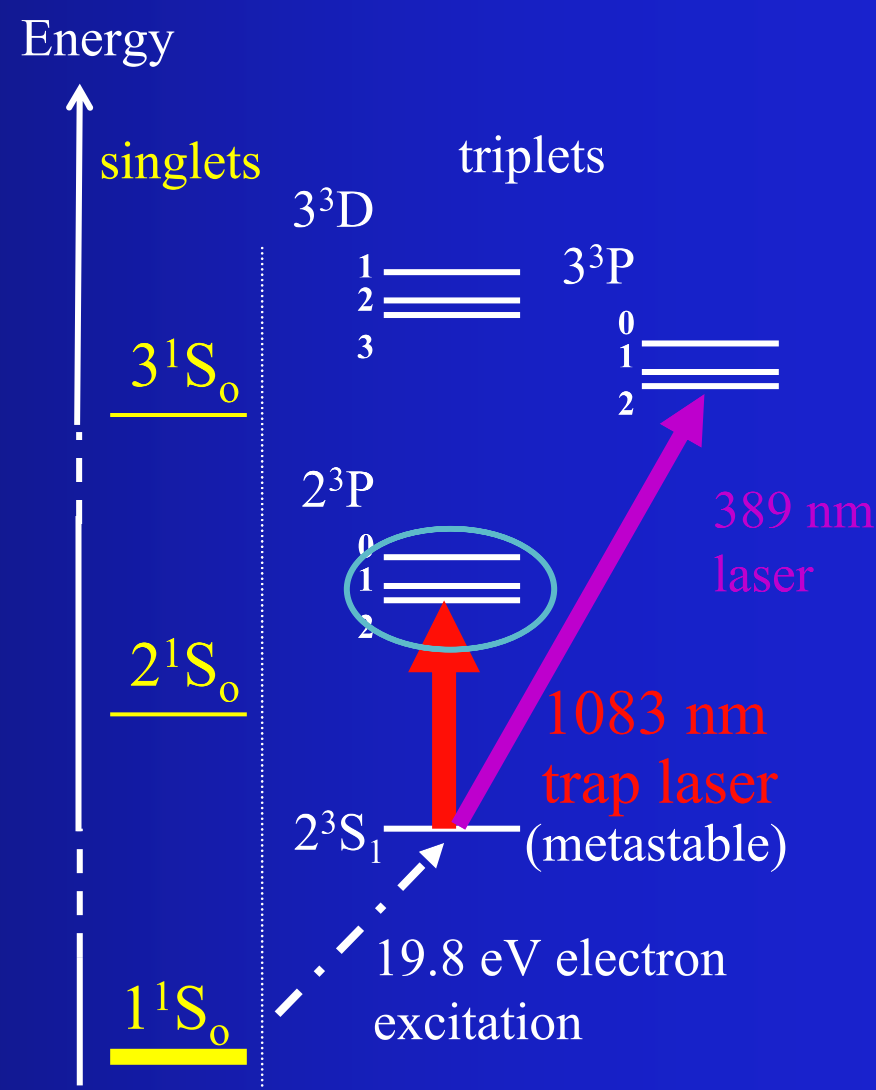
Metastable Helium Atom Optics

- He 2^3S_1 (He*) is the longest lived (~8000s) atomic metastable state yet measured. See -

  “Metastable helium: Atom optics with nano-grenades” , K.G.H. Baldwin, Contemporary Physics **46**, 105 (2005).

- We first developed a “bright” He* beam line for *cold* atom studies
  - Electron - He* collisions
  - Atom lithography
  - Atom guiding in hollow fibres
- We now have a He* BEC apparatus for *ultracold* atom and BEC studies
  - Atom laser studies
  - Quantum statistical effects
  - Atomic physics - He* lifetimes



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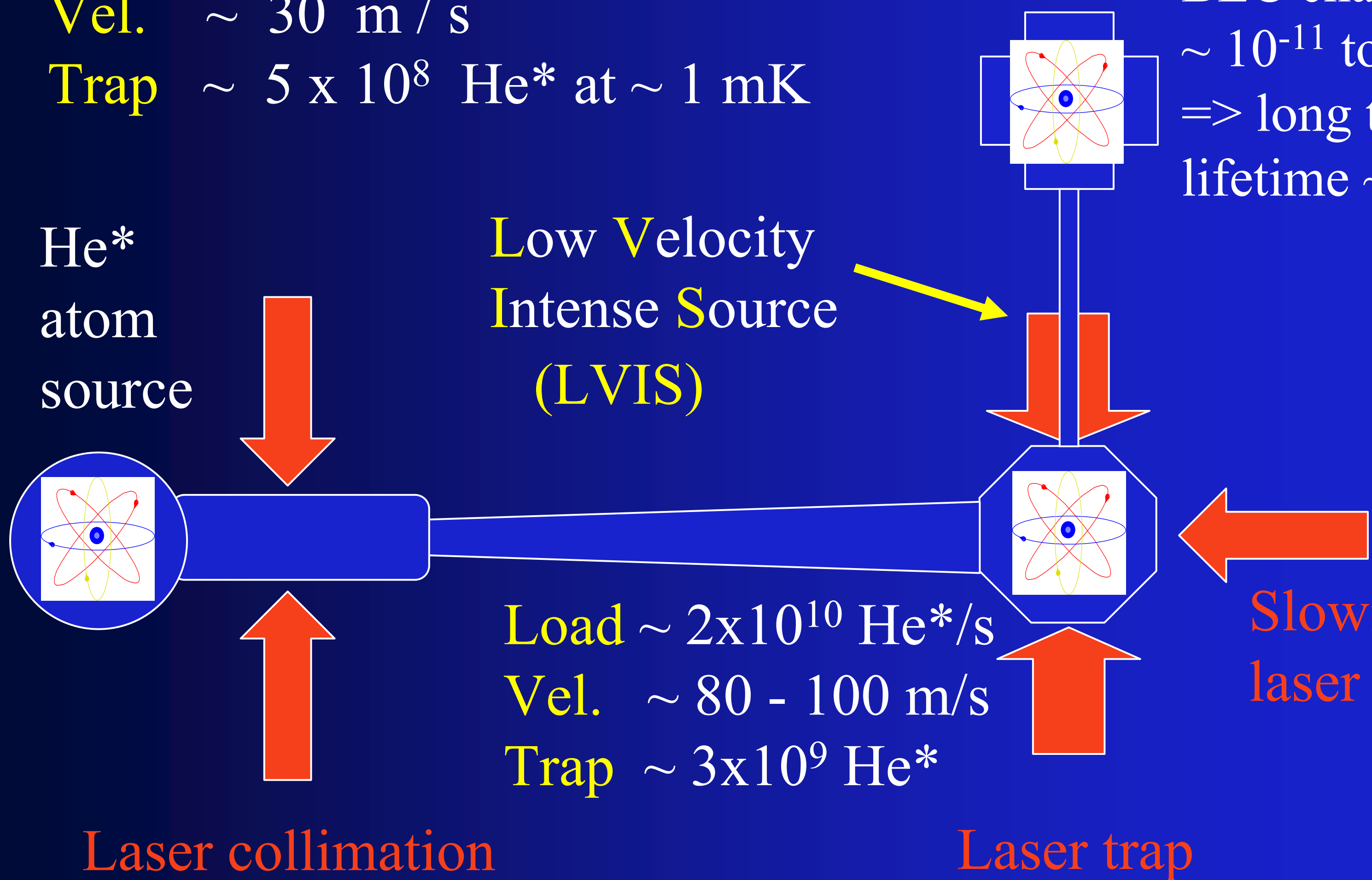
He* BEC Facility

LVIS ~ 2 x 10^{10} He* / s
Vel. ~ 30 m / s
Trap ~ 5 x 10^{8} He* at ~ 1 mK

BEC chamber
~ 10^{-11} torr
=> long trap
lifetime ~ 60s



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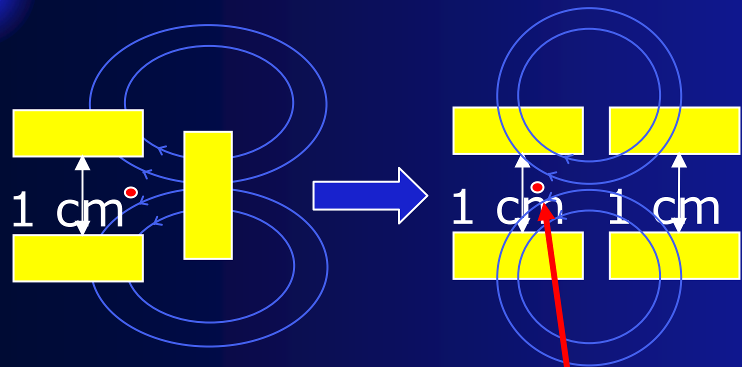
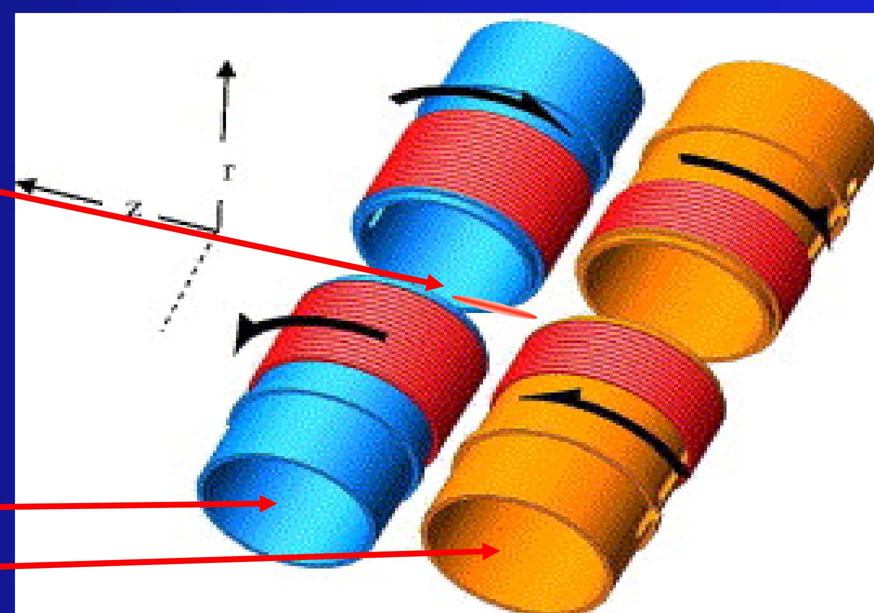
Magnetic Trap



Equivalent coil configurations

BEC
~ 3×10^6 He* at
~ 1μK

Highly stable magnetic field trapping potential ~10^{-5} gauss



BiQUIC magnetic trap coils

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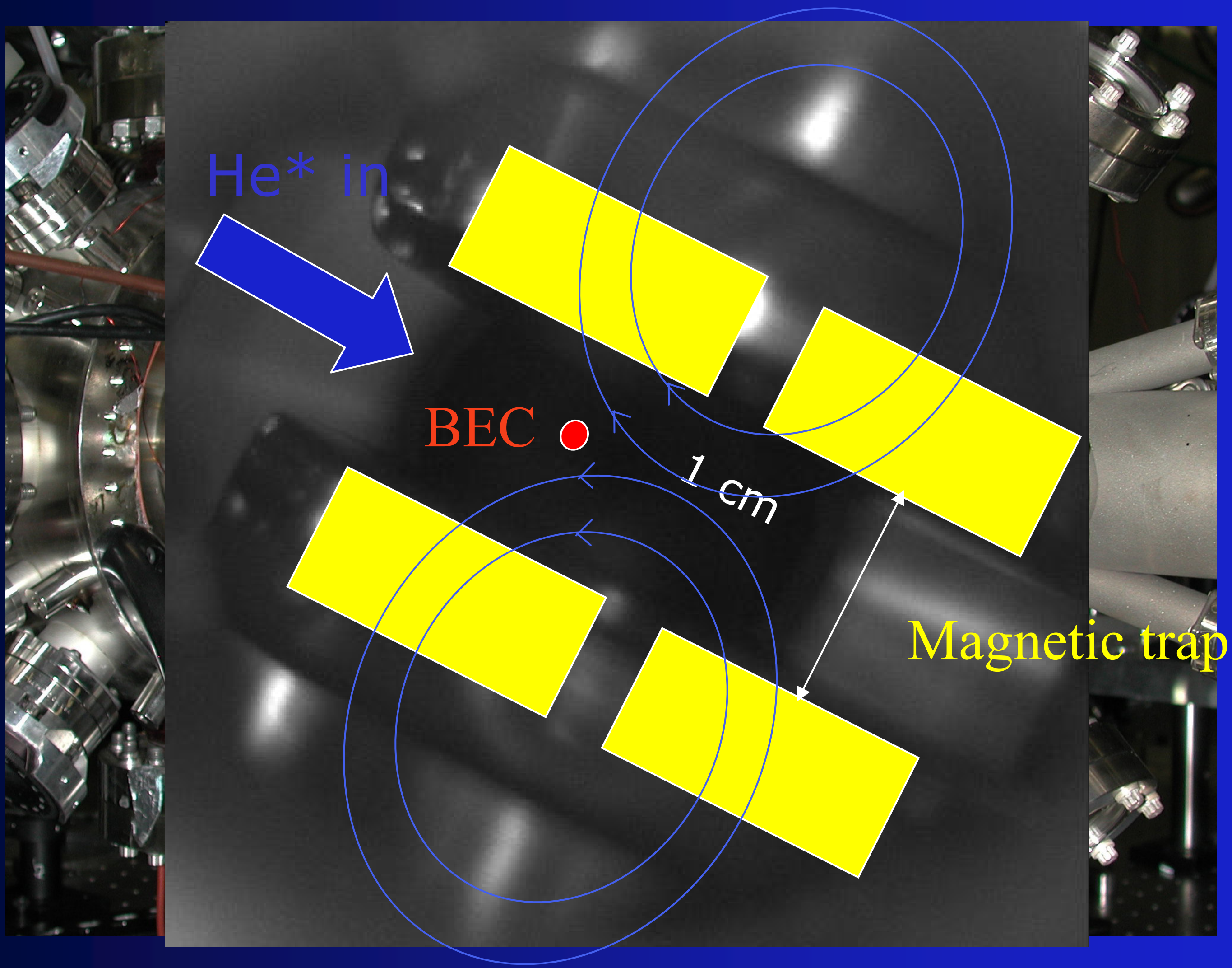
BEC chamber



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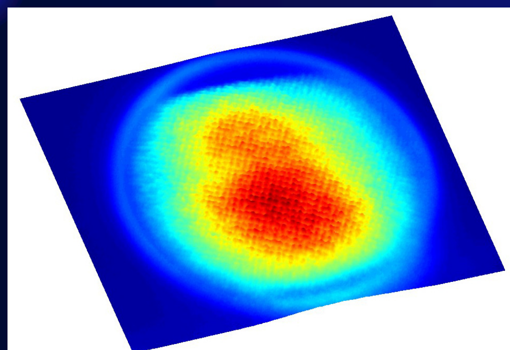
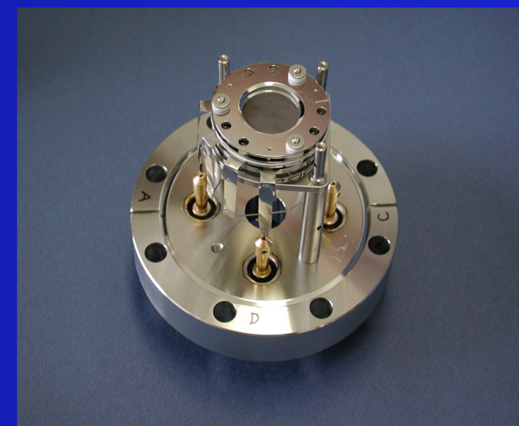
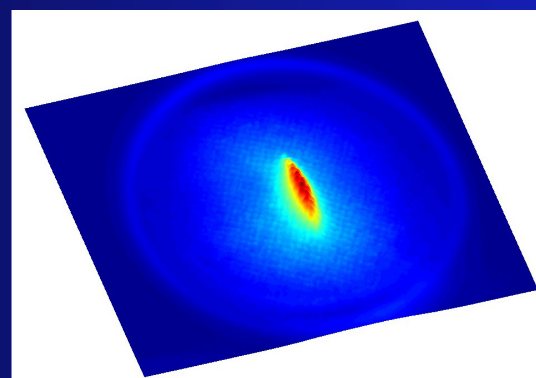
He* BEC Experiments: 2D spatial profile



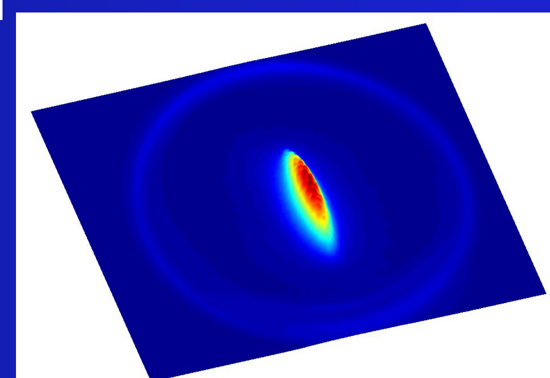
$T > T_c$

MCP and phosphor 2-D detector





$T < T_c$



$T \sim 0.3T_c$

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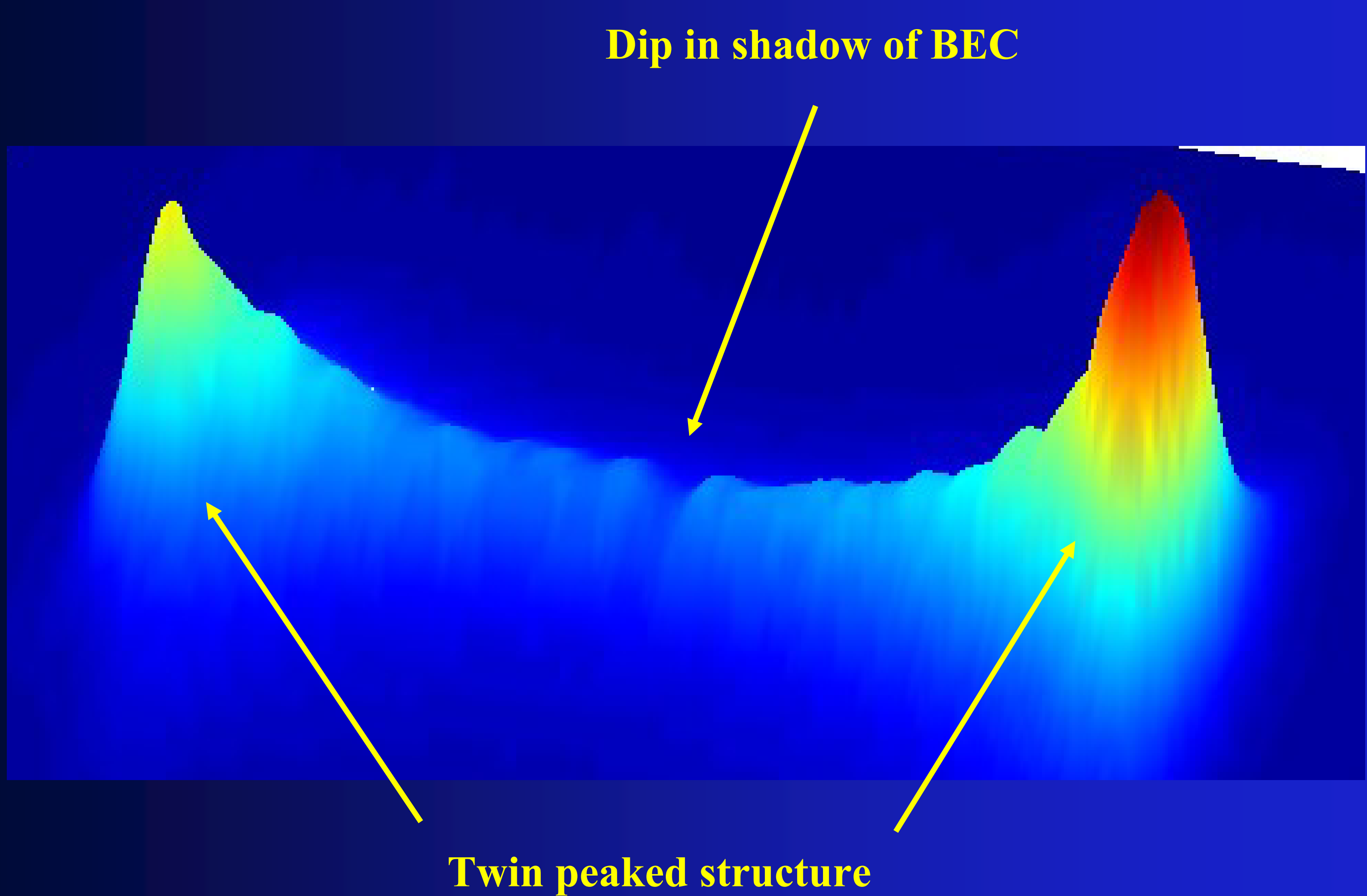
Atom Laser Profile



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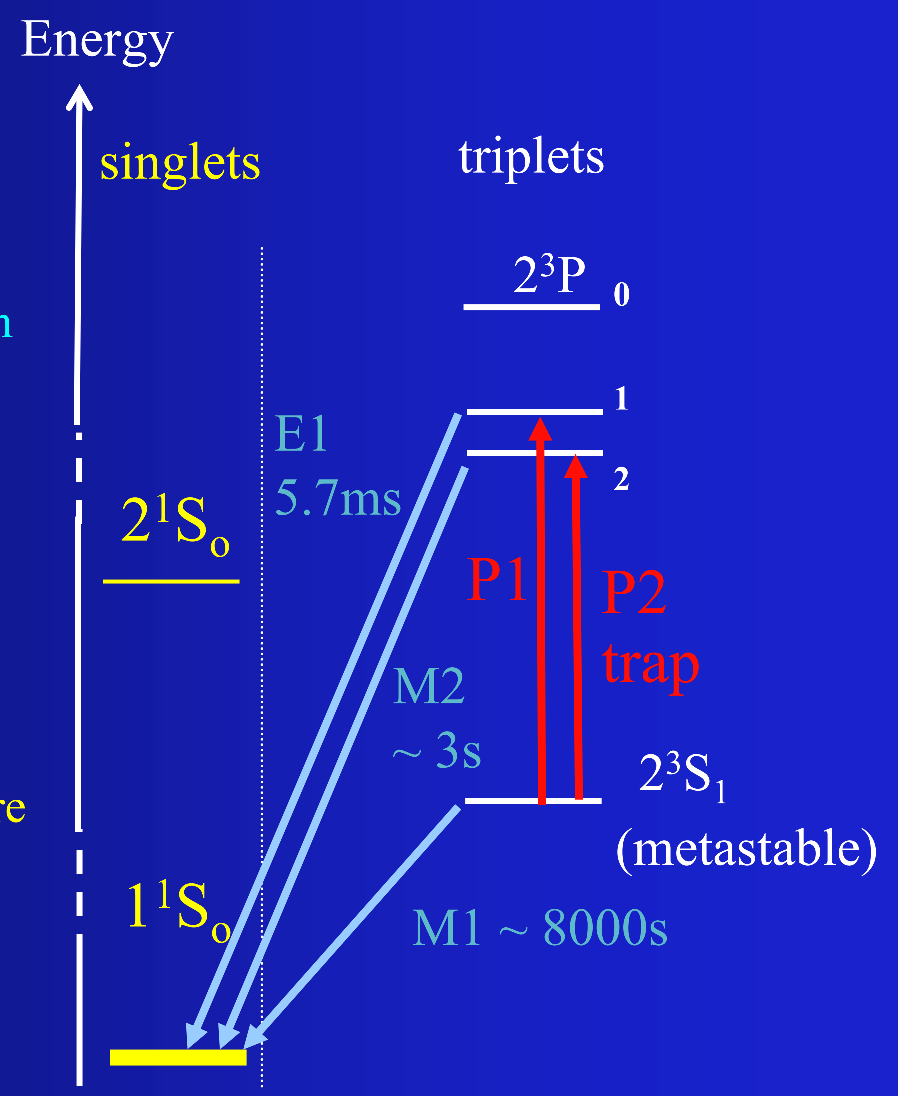
He* atomic physics: decay rates

- He 2^3S_1 is the longest metastable atomic lifetime yet measured
  - Moos & Woodworth (1975) 9000 s ± 30%
  - magnetic dipole (M1) transition
  - ~ 8000 s predicted lifetime
- He 2^3P_2 decay to 1^1S_0 has yet to be measured
  - magnetic quadrupole (M2)
  - ~ 3 s predicted decay time
- He 2^3P_1 decay to 1^1S_0 measured here for the first time
  - electric dipole (E1) inter-combination transition
  - ~ 5.7 ms predicted decay time



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2^3P_1 - 1^1S_0 decay rate

CURRENT EXPERIMENTAL/THEORETICAL STATUS

Theoretical Calculations		
Reference	**Transition Rate (s^{-1})**	**Lifetime (ms)**
R. Elton, Astro. Journal, **148**, 573 (1967)	160.00	6.25
G.W.F. Drake, Astro. Journal, **157**, 459 (1969)	180.18	5.55
G.W.F. Drake, J. Phys. B **9**, L169 (1976)	176.40	5.67
W.R. Johnson et al., Adv. At. Mol. Opt. Phys. **35**, 255 (1995)	175.70	5.69
G.Lach & K.Pachucki, Phys.Rev.A **64**, 042510 (2001)	177.5771	5.6314

Unpublished **Experimental Measurements**		
Reference	**Transition Rate (s^{-1})**	**Lifetime (ms)**
H.Y.S. Tang and W. Happer, Bull. Am. Phys. Soc. **17**(4), 476 (1972)	30 ² Γ_1 ² 200	5 ² τ_1 ² 3 3.3
Institut dŒOptique, Orsay - thesis by Julie Poupard (2000)	62 ± 14	16 ± 4
Trapped Atoms - 2 data processing methods	59 ± 14	17 ± 4
Free Atoms (factor of 2 error)	182 100	5.5 10

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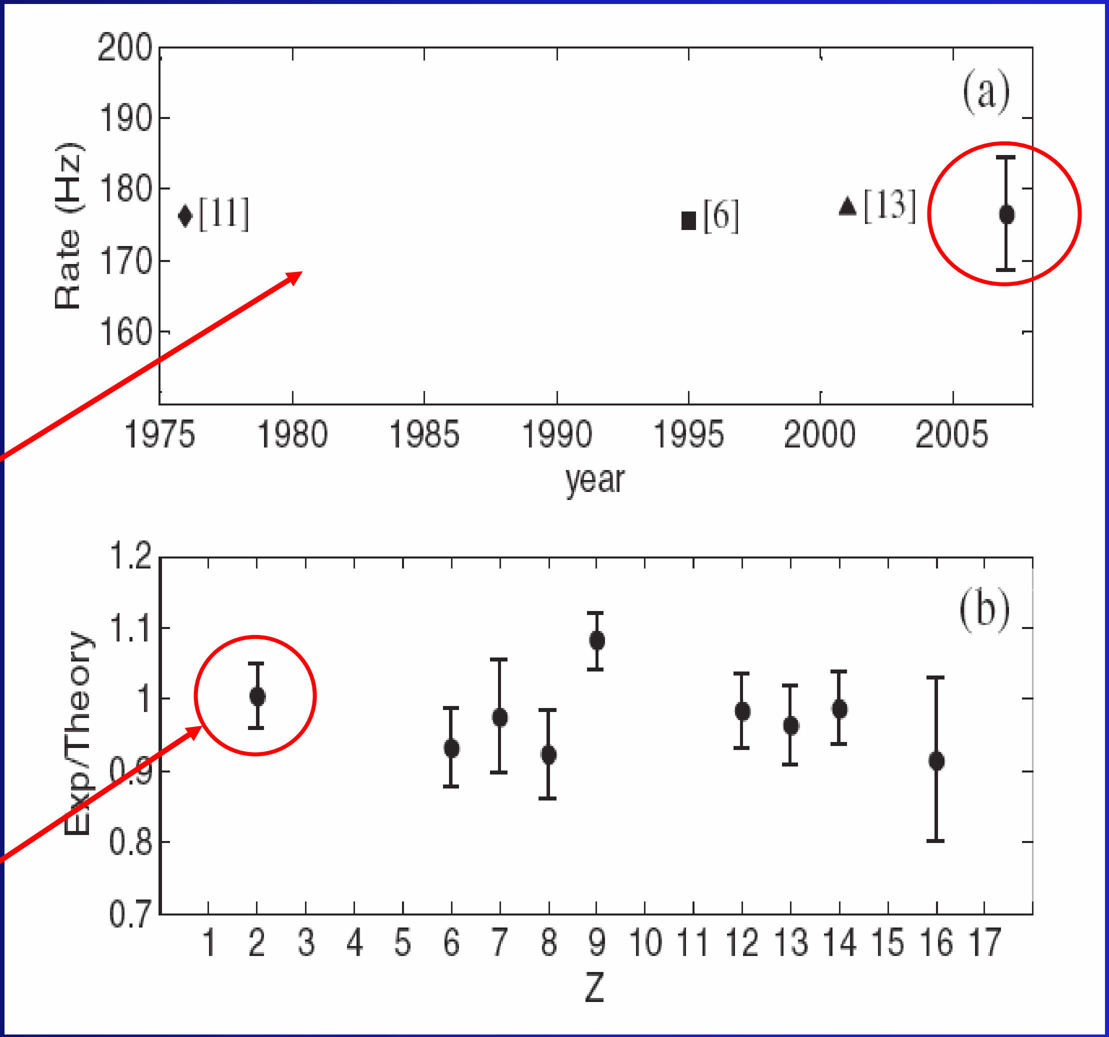
2^3P_1- 1^1S_0 isoelectronic sequence

- Atomic energy levels known to 1 in 10^{11} (cw) or 1 in 10^8 (pulsed)
- But decay rates only known to few %
- For this transition in He, theories differ by 1% (similar uncertainty)
- Until now, in the He-like 2^3P_1- 1^1S_0 isoelectronic sequence, there has been no measurement for He



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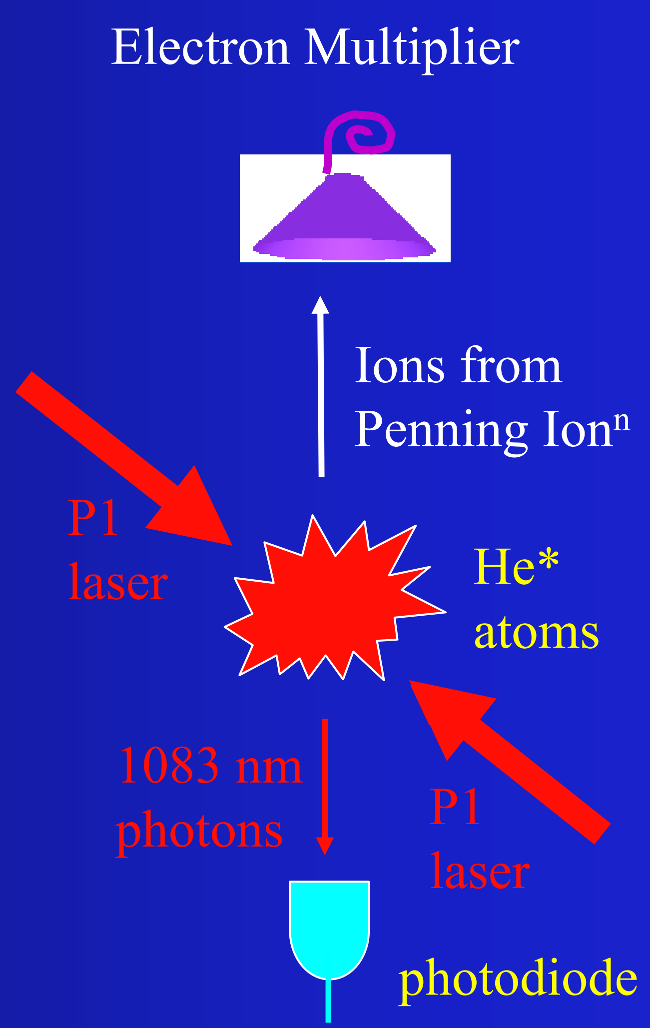
Experiment: He 2^3P_1 lifetime

- Trap He* atoms with P2 light
- Release atoms and turn on weak P1 light to measure fluorescence
- Then saturate P1 light to yield P1 population fraction
- Re-load MOT and *measure ions from Penning collisions* $\alpha\ N_{He^*}$
- Then switch off loading and allow to decay for ~16s until dominated by *single body background collisions*
- Turn off P2 light and turn on P1
- Repeat with no P1 light and remove background single body decay by ratioing



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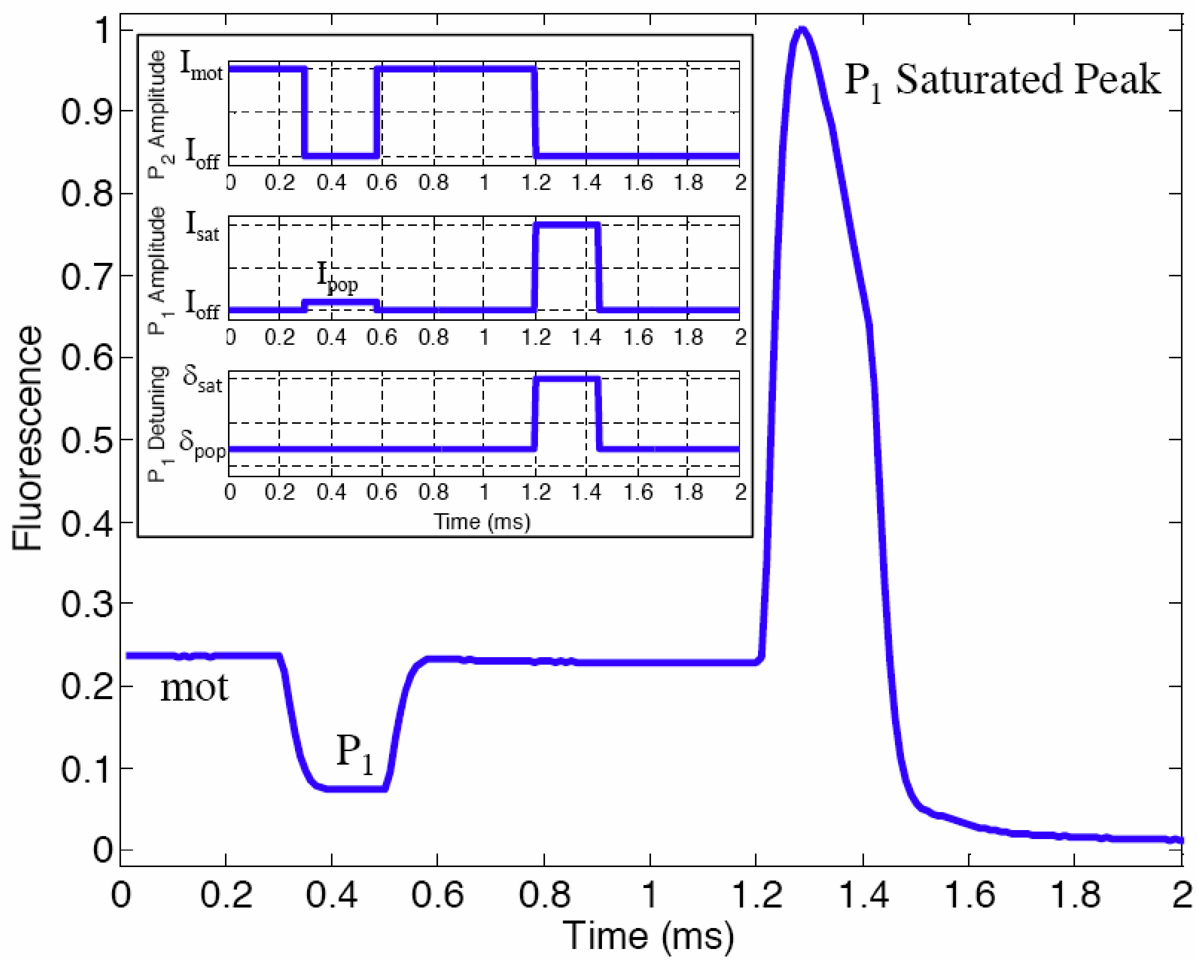
Experiment: P1 population fraction



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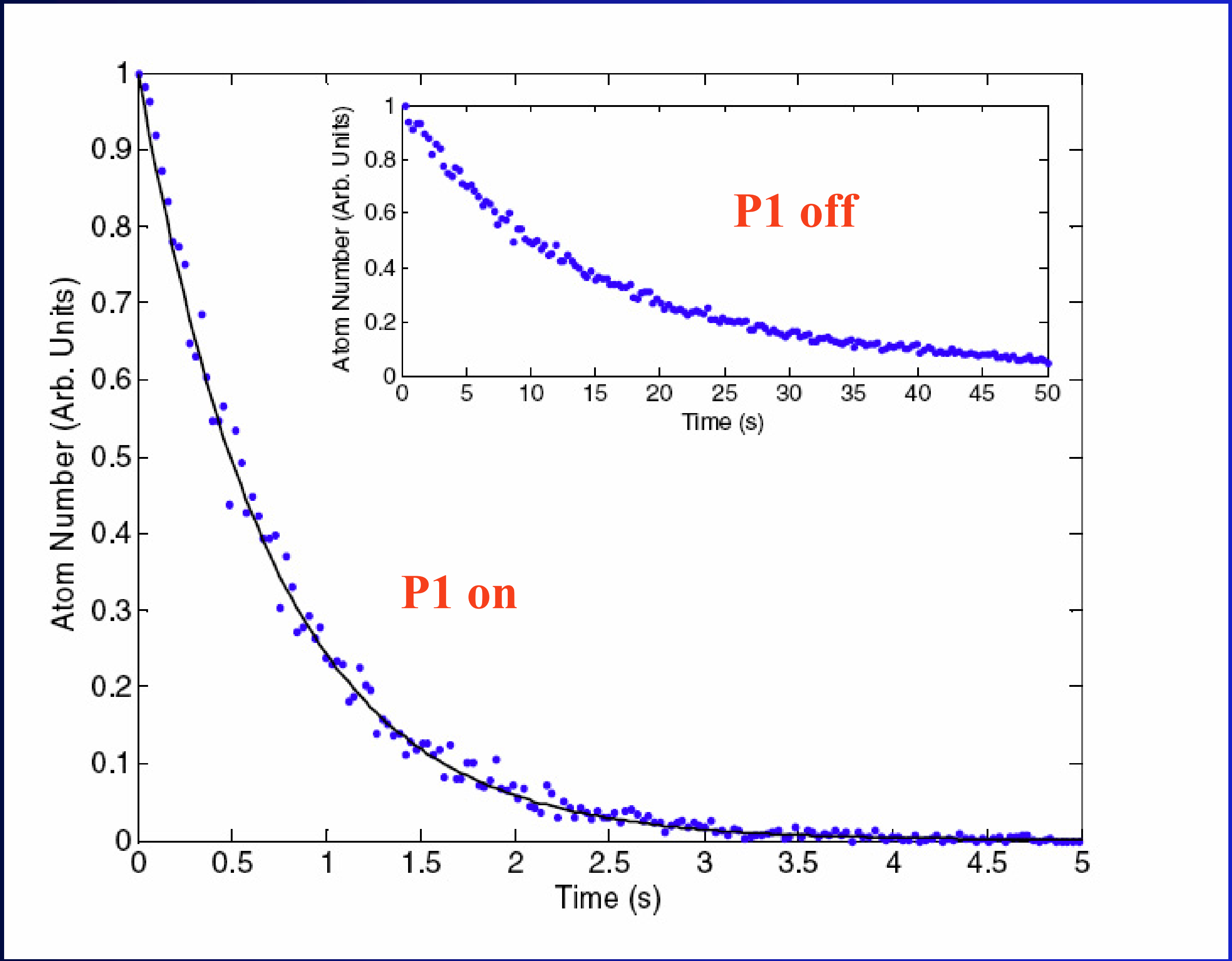
Experiment: Trap decay curves



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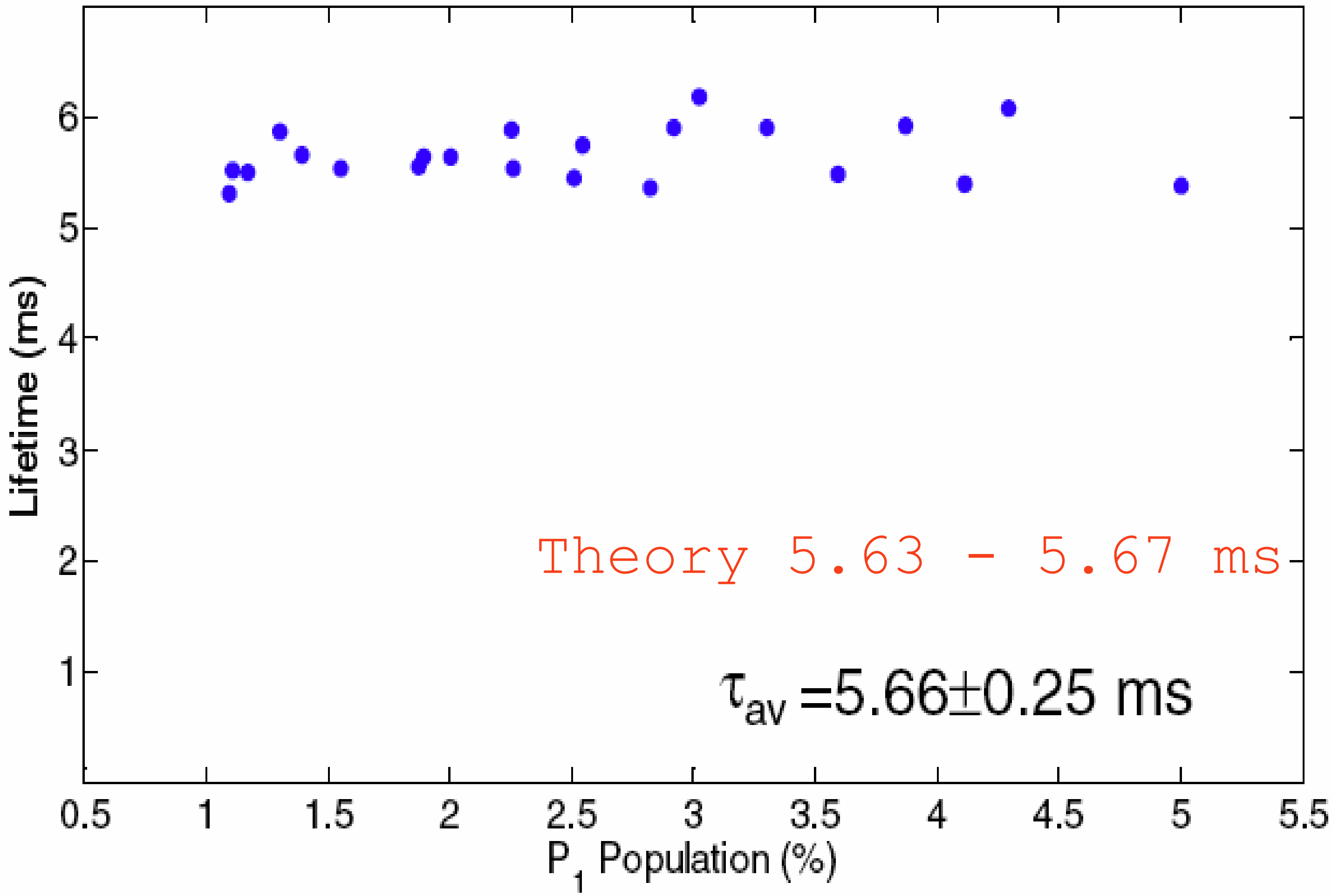
Results: He 2^3P_1 decay time

PRL **100**, 023001 (2008)



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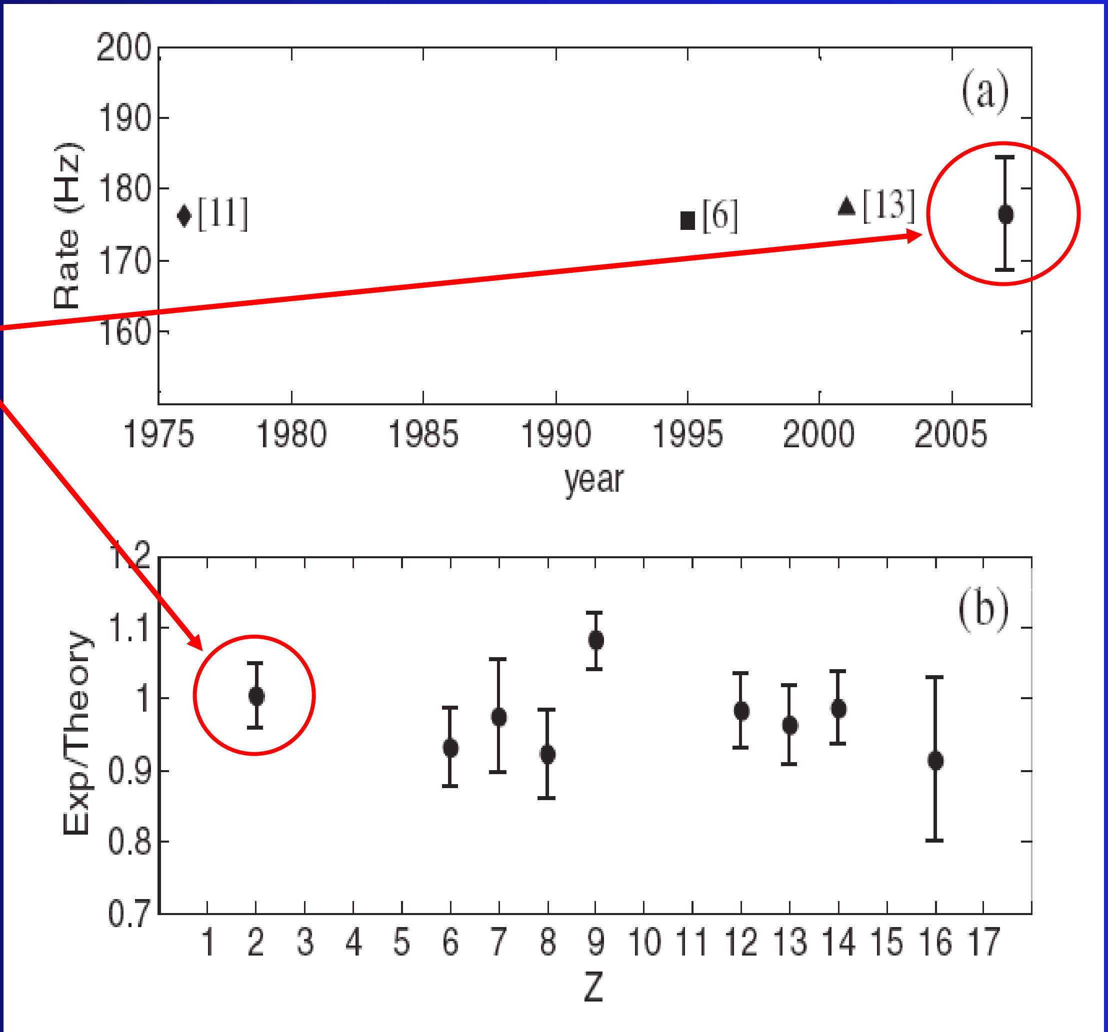
2^3P_1 - 1^1S_0 decay rate to test QED

- This is the first experimental measurement for the He 2^3P_2 - 1^1S_0 transition PRL **100**, 023001 (2008)

- The value for He anchors the 2^3P_2 - 1^1S_0 isoelectronic sequence

- Uncertainty is less than for most measurements in the sequence



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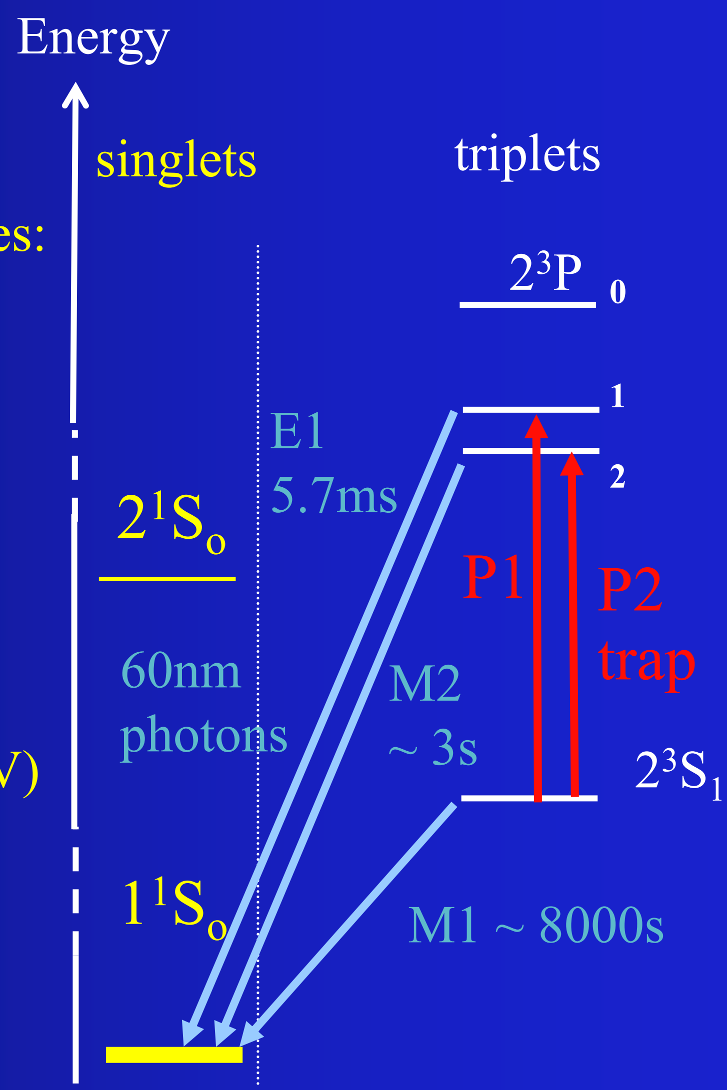
The future: He 2^3S_1, 2^3P_2 lifetime

- Theory predicts the following decay times:
  - 2^3S_1 ~ 7860 s via M1 transition
  - 2^3P_2 ~ 3 s via M2 transition
- We have measured
  - 2^3P_1 ~ 5.7 ms via E1 transition
- All decay via radiation at ~ 60nm (~20eV)



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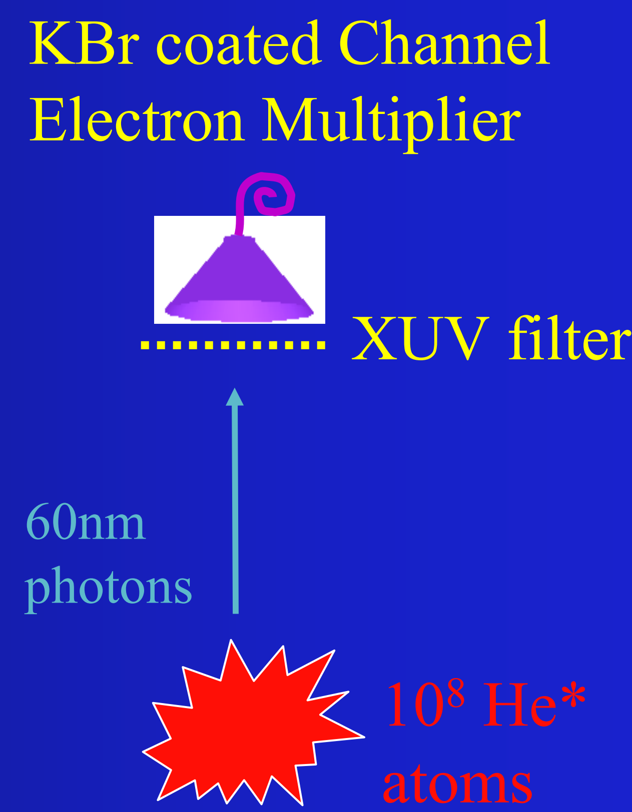
He 2^3S_1, 2^3P_2 lifetime experiment

- Aim to measure the XUV emission from ~ 10^8 ultracold He* atoms released from the magnetic trap
- Filter radiation > 70nm
- Need only to measure the ratio of 2^3S_1 and 2^3P_2 count rate to 2^3P_1 count rate
- Use the 2^3P_1 decay rate measured in our first experiment as a calibration
- Don't need to measure the absolute number of atoms



2^3P_2- 1^1S_0 decay rate

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CURRENT EXPERIMENTAL/THEORETICAL STATUS

Theoretical Calculations

Reference	Transition Rate (s^{-1})	Lifetime (s)
G.W.F. Drake, Astro. Journal, **158**, 1199-1203, (1969)	0.446	2.24
R.H. Garstang, Astro. Journal, **148**, 579-584, (1967)	0.220	4.54
R.H. Garstang, Astro. Journal, **148**, 579-584, (1967)	0.327	3.06
C.D. Lin et al., Phys. Rev. A, **15**(1), 154-161, (1977)	0.394	2.54
G.Lach and K.Pachucki, Phys.Rev.A **64**, 042510 (2001)	0.327	3.06

Unpublished **Experimental Measurements**

Reference	Transition Rate (s^{-1})	Lifetime (s)
Orsay Thesis by Julie Poupard (2000) (determined by the Γ_2/Γ_1 branching ratio)	0.28 ± 0.07	3.6 ± 0.9

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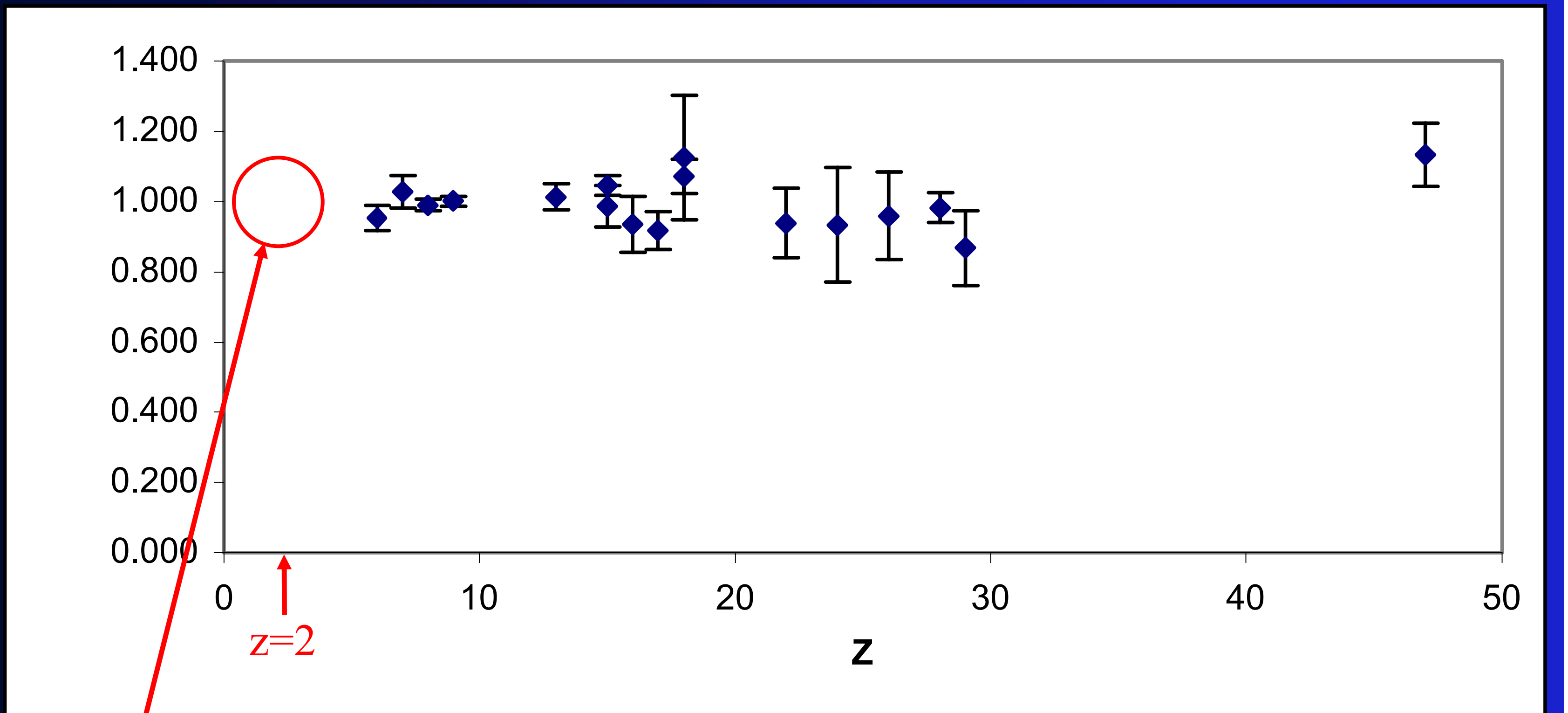
2^3P_2- 1^1S_0 decay rate



- For the 2^3P_2 - 1^1S_0 transition there is no He experimental measurement
- Most recent predicted decay time ~ 3 s

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2^3S_1- 1^1S_0 decay rate

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Current Experimental/Theoretical State

Theoretical Calculations		
Reference	**Transition Rate (s^{-1})**	**Lifetime (s)**
G.W.F. Drake, Phys. Rev. A **3**, 908 (1971)	1.272E-04	7861
G. Feinberg et al. Phys. Rev. Lett. **26**, 681 (1971)	1.200E-04	8333
W.R. Johnson et al., Adv. At. Mol. Opt. Phys. **35**, 255 (1995)	1.266E-04	7899
G. Lach and K. Pachucki, Phys. Rev. A **64**, 042510 (2001)	1.272426E-04	7859
Experimental Measurements		
Reference	**Transition Rate (s^{-1})**	**Lifetime (s)**
H.W. Moos and J.R. Woodworth, Phys. Rev. Lett. **30**, 775 (1973)	2.35E-04 with factor of three error	4260
H.W. Moos and J.R. Woodworth, Phys. Rev. A **12**, 2455 (1975)	1.10E-04 with 30% error	9090

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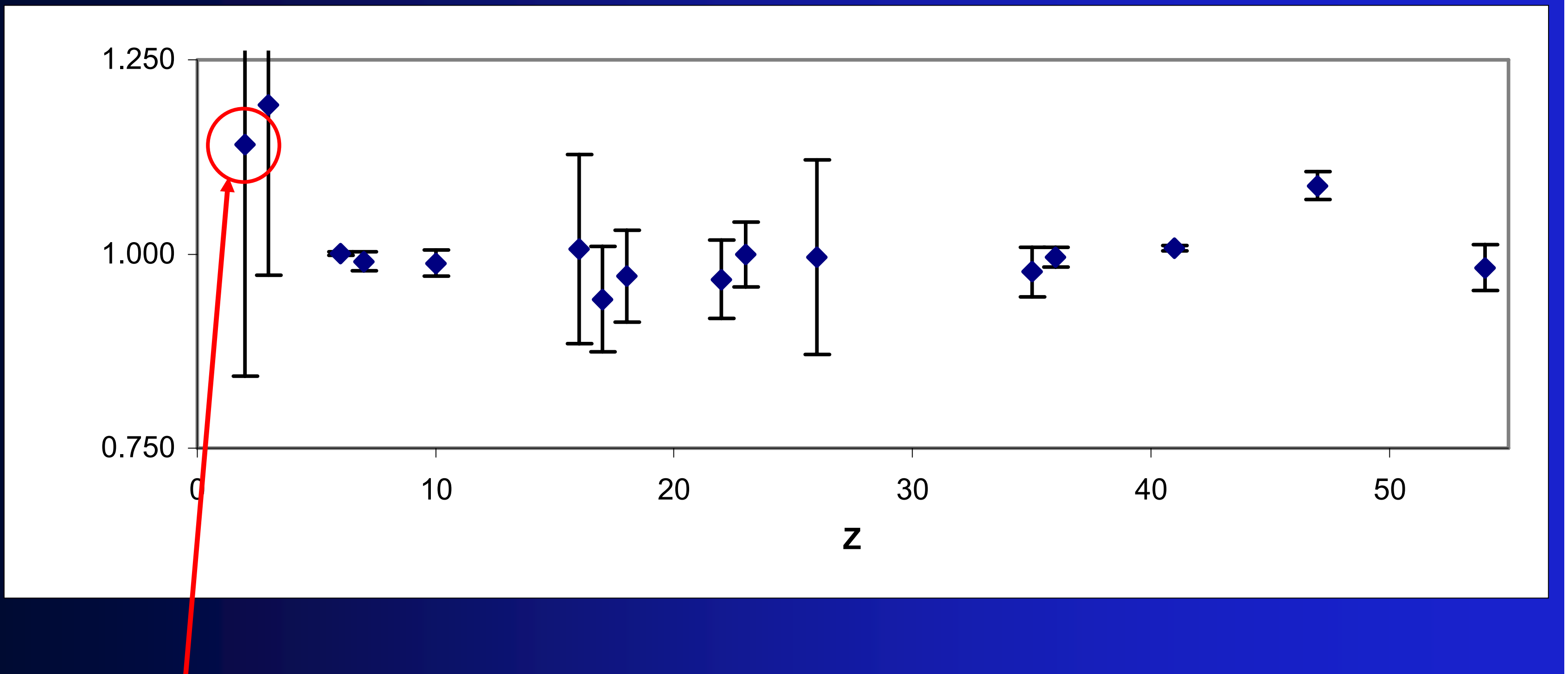
2^3S_1- 1^1S_0 decay rate



- Only measurement (Moos and Woodworth, 1975) in a discharge source gave ~ 9,000s with 30% uncertainty
- Most recent predicted decay time ~ 7,900 s

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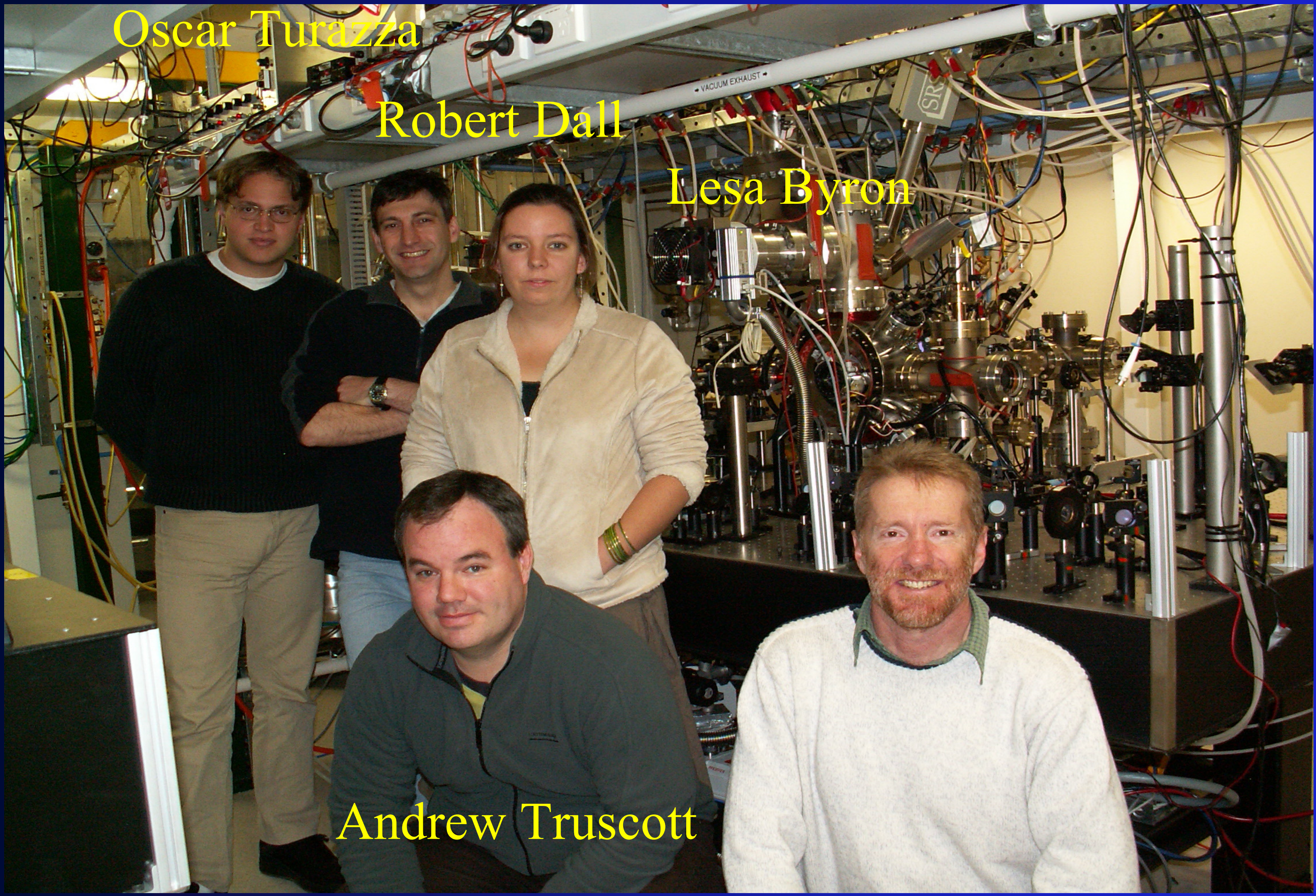
ACQAO He* BEC experiment



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Ultracold
Precision
Physics

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Thank you !

Blue Lake, Snowy Mountains,
Australia, 2004

ICAP 2010 Cairns, 25 - 30 July

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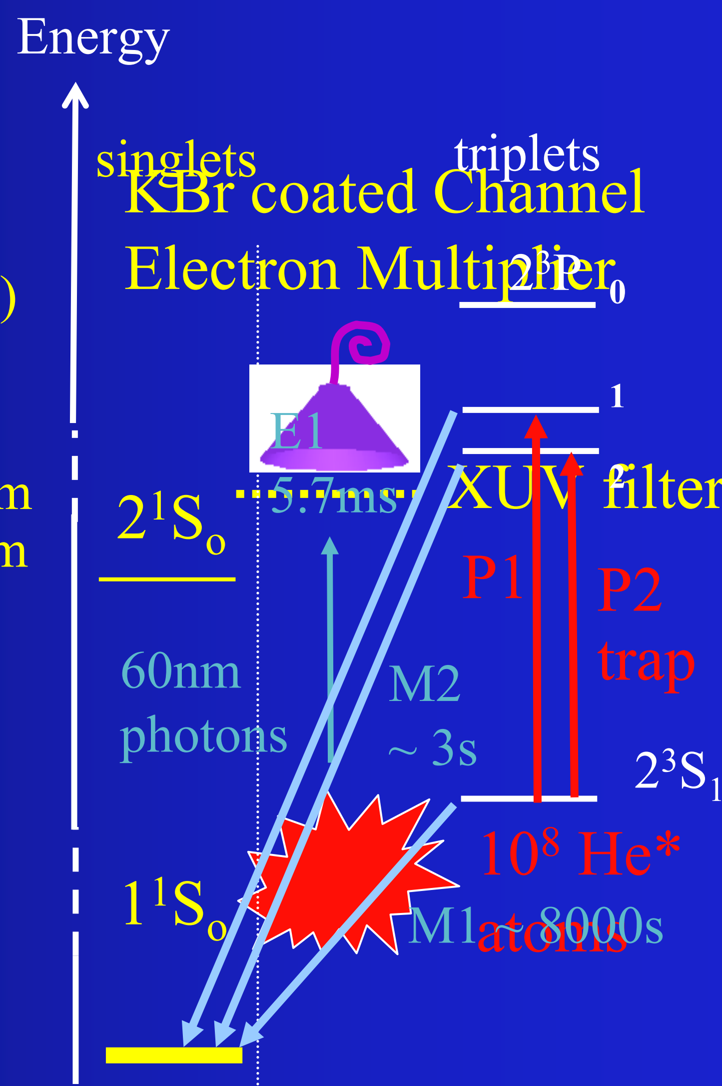
The future: He 2^3S_1, 2^3P_2 lifetime

- Theory predicts the following decays:
  - 2^3S_1 ~ 7860s via M1 transition
  - 2^3P_2 ~ 3s via M2 transition

  Decay via radiation at ~ 60nm (~ 20eV)

- Aim to measure the XUV emission from ~ 10^8 ultracold He* atoms released from the magnetic trap

- Need only to measure the ratio of 2^3S_1, 2^3P_2 intensity to 2^3P_1 intensity, and use the P1 decay rate measured in our first experiment as a calibration



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