

Title: Measurements of blackbody-radiation-induced transition rates between high-lying S, P, and D Rydberg levels

Speakers: Donatella Ciampini

Collection: Cold Atom Molecule Interactions (CATMIN)

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Abstract: We report experimental measurements of the rates of blackbody-radiation-induced transitions between highlying ($n > 60$) S, P, and D Rydberg levels of rubidium atoms in a magneto-optical trap using a hybrid field ionization and state-selective depumping technique. Our results reveal significant deviations of the measured transition rates from theory for well-defined ranges of the principal quantum number. We assume that the most likely cause for those deviations is a modified blackbody spectrum inside the glass cell in which the magneto-optical trap is formed, and we test this assumption by installing electrodes to create an additional microwave cavity around the cell. From the results, we conclude that it should be possible to use such external cavities to control and suppress the blackbody-radiation-induced transitions."

Measurements of blackbody-radiation-induced transition rates between high-lying S, P, and D Rydberg levels

Donatella Ciampini

Università di Pisa and INO-CNR, Pisa, Italy

CATMIN 2022, 15/7/2022



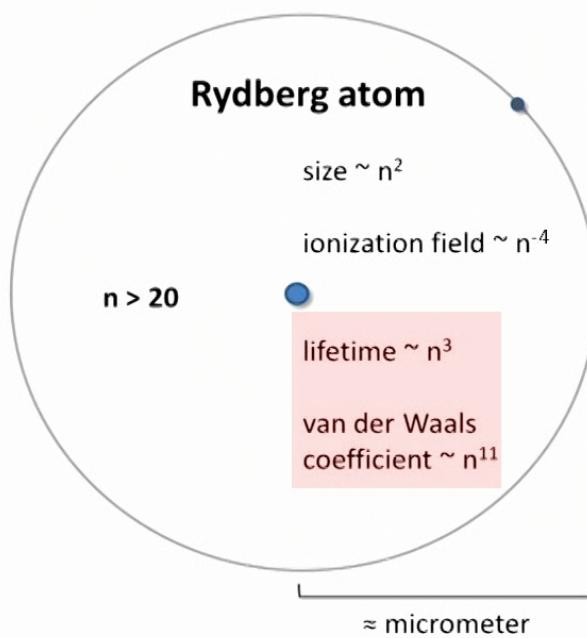
M. Archimi, M. Ceccanti, M. Distefano, L. Di Virgilio, R. Franco, A. Greco, A. Simonelli

E. Arimondo, O. Morsch

Collaboration: I. Beterov, I. Ryabtsev



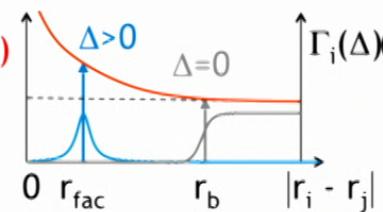
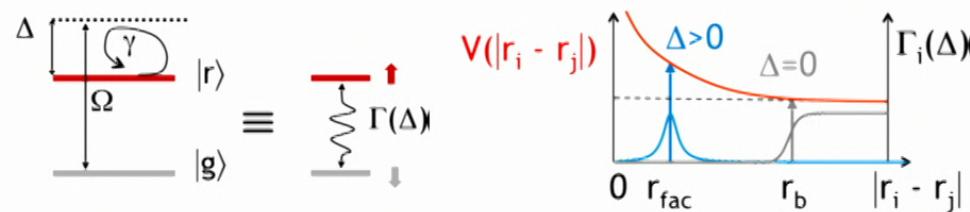
Rydberg atoms are long-lived, interact strongly...



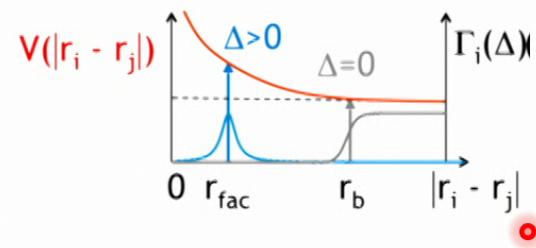
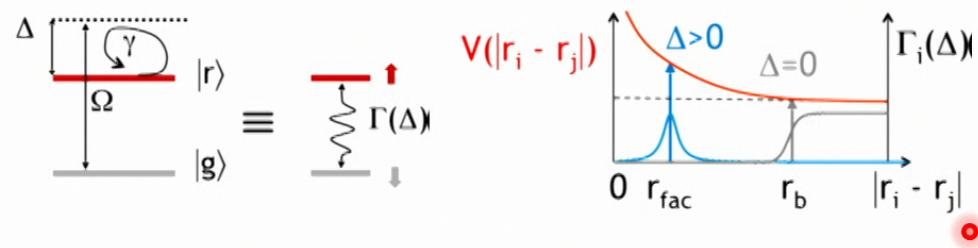
Ex.: Rb $n=70$, \sim MHz at $10 \mu\text{m}$
lifetime around $150 \mu\text{s}$

QUANTUM COMPUTATION
QUANTUM SIMULATION
QUANTUM METROLOGY

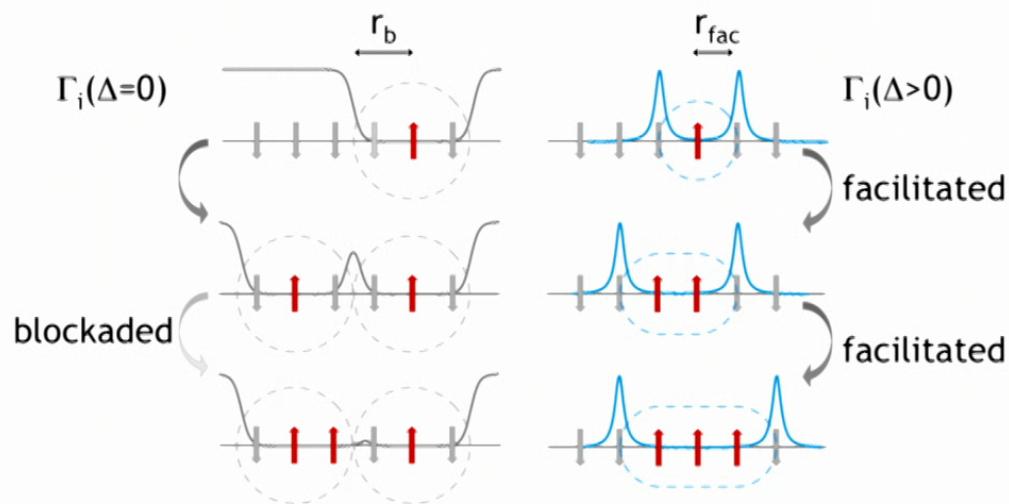
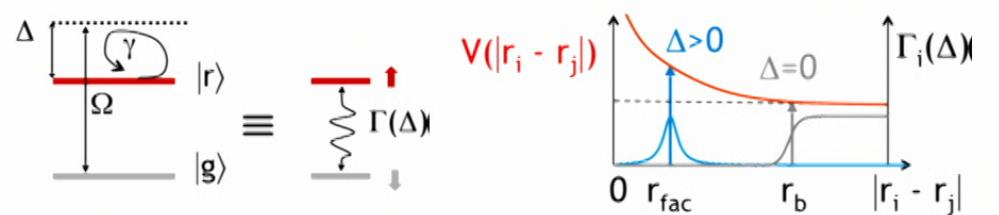
... and give rise to strongly correlated dynamics



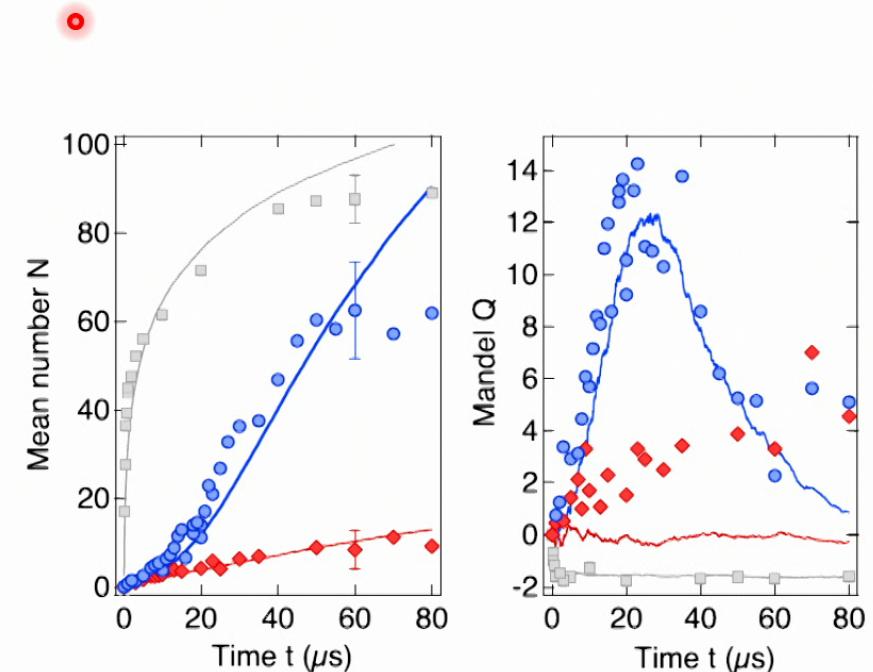
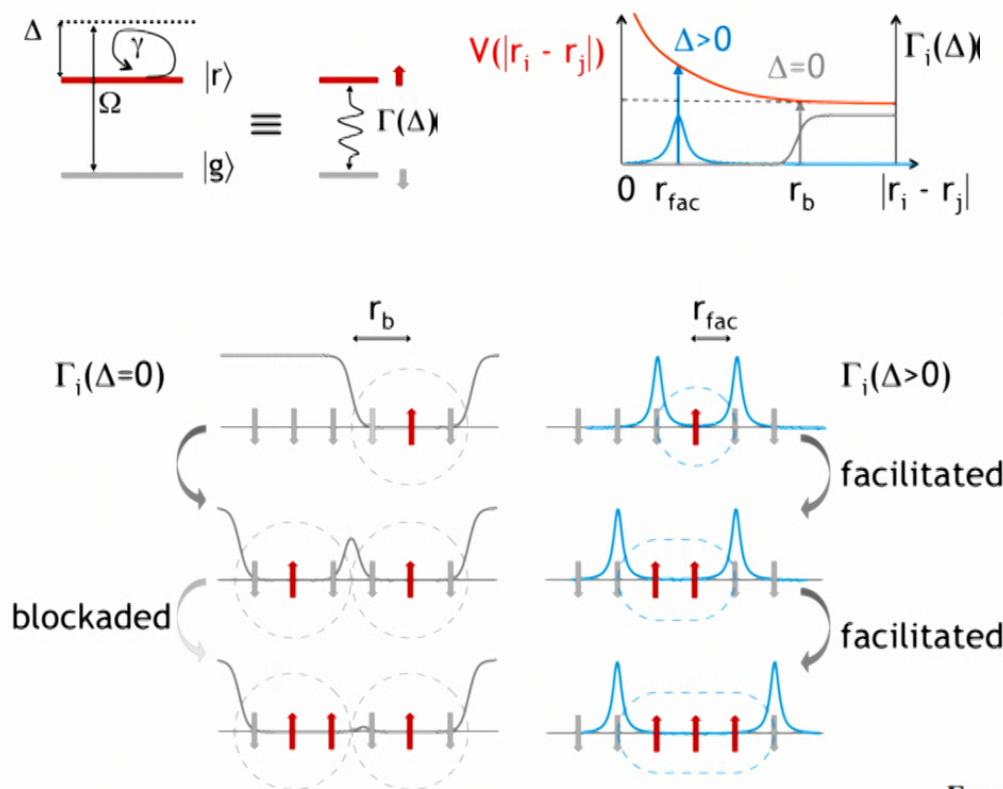
... and give rise to strongly correlated dynamics



... and give rise to strongly correlated dynamics



... and give rise to strongly correlated dynamics

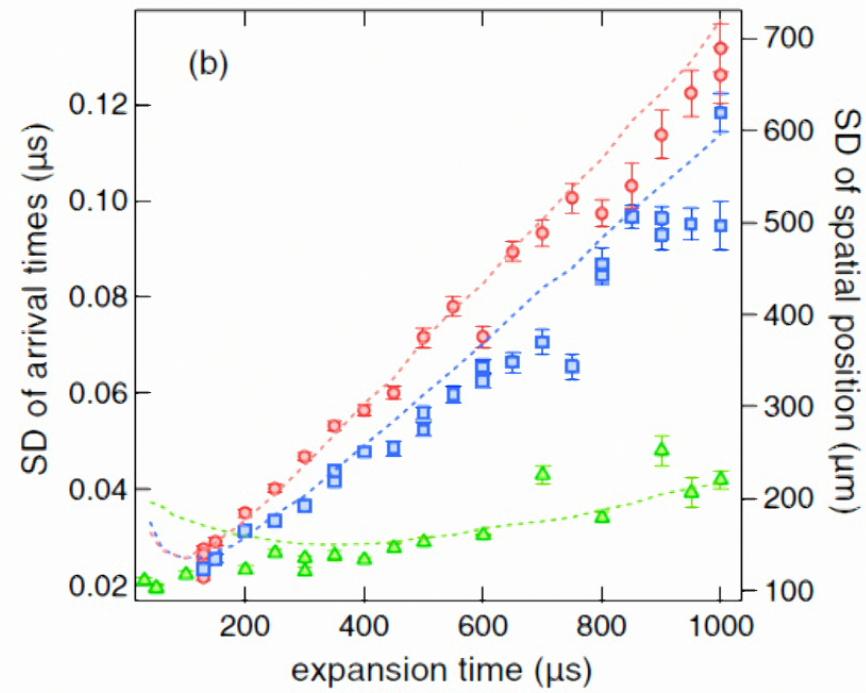
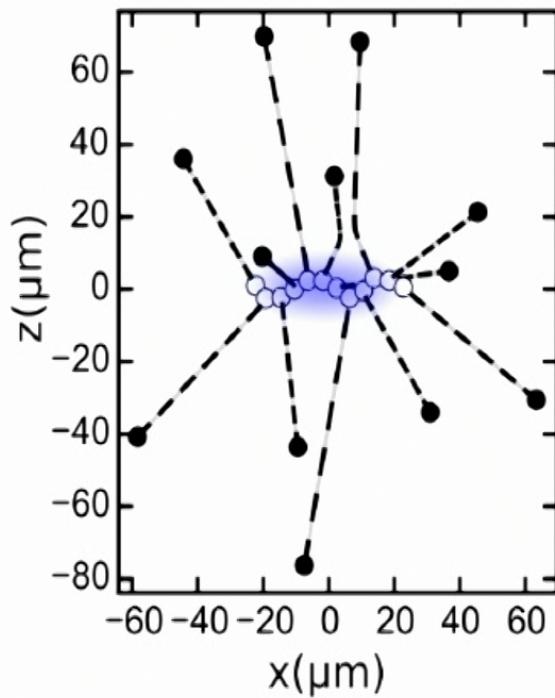


PHYSICAL REVIEW A 93, 040701(R) (2016)



Experimental observation of controllable kinetic constraints in a cold atomic gas

... and give rise to strongly correlated dynamics



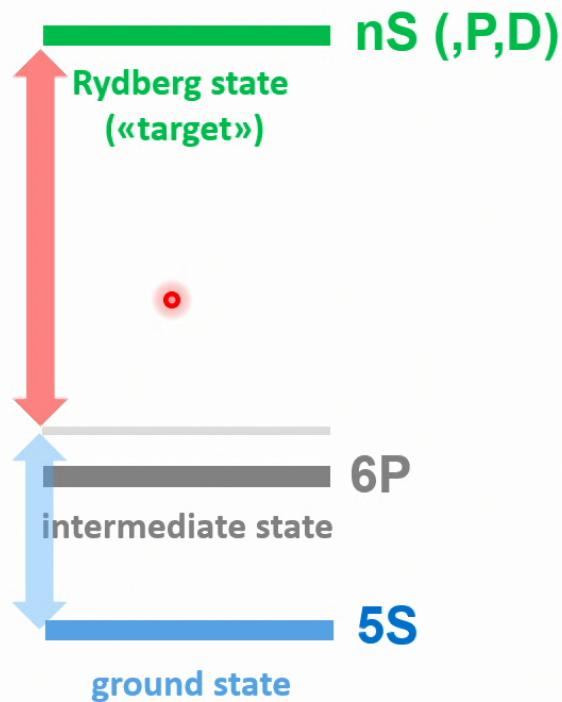
PHYSICAL REVIEW A 93, 030701(R) (2016)

van der Waals explosion of cold Rydberg clusters

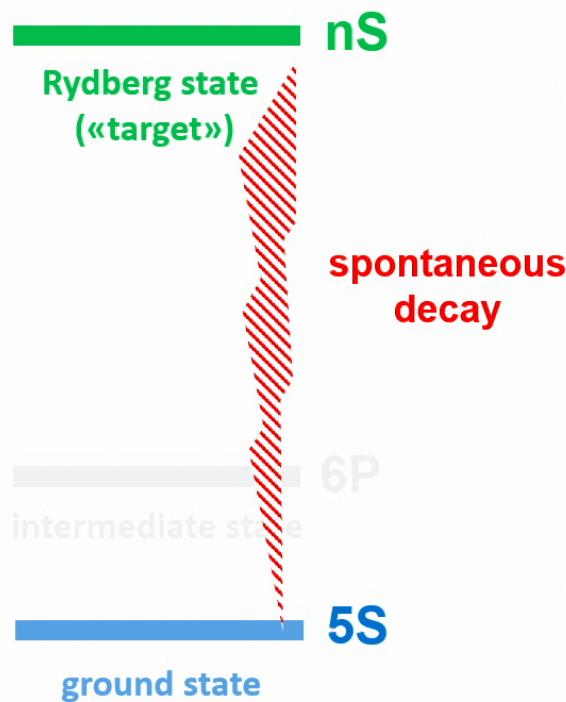
How «ideal» is our model?



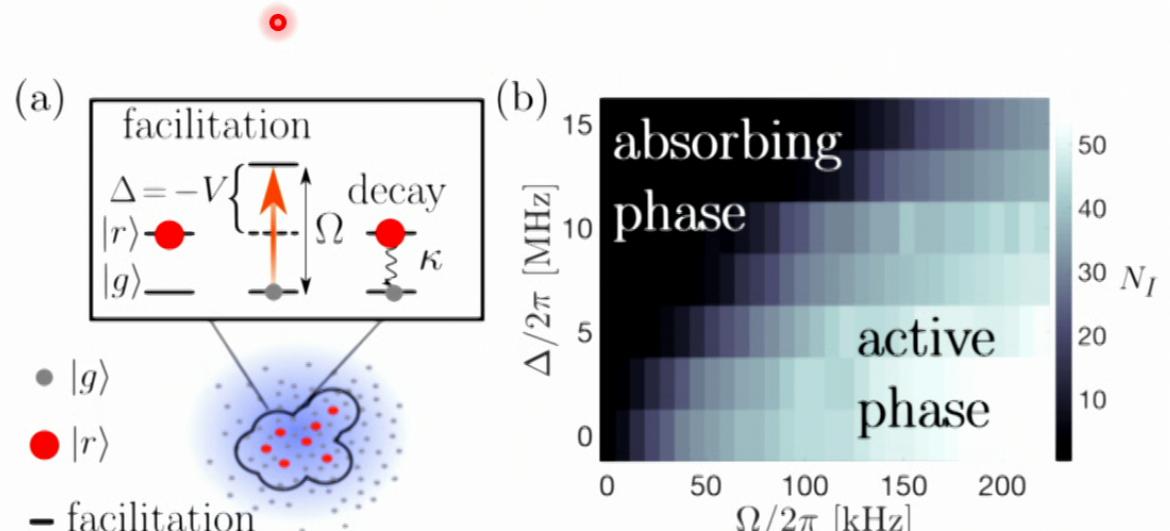
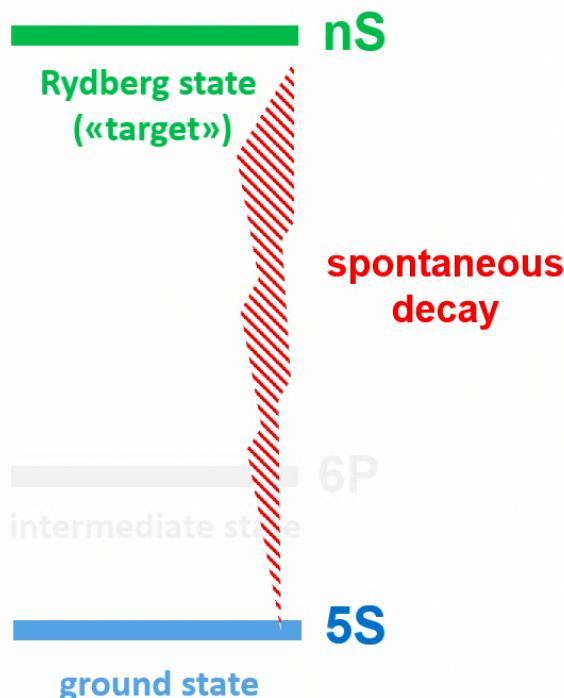
How «ideal» is our model?



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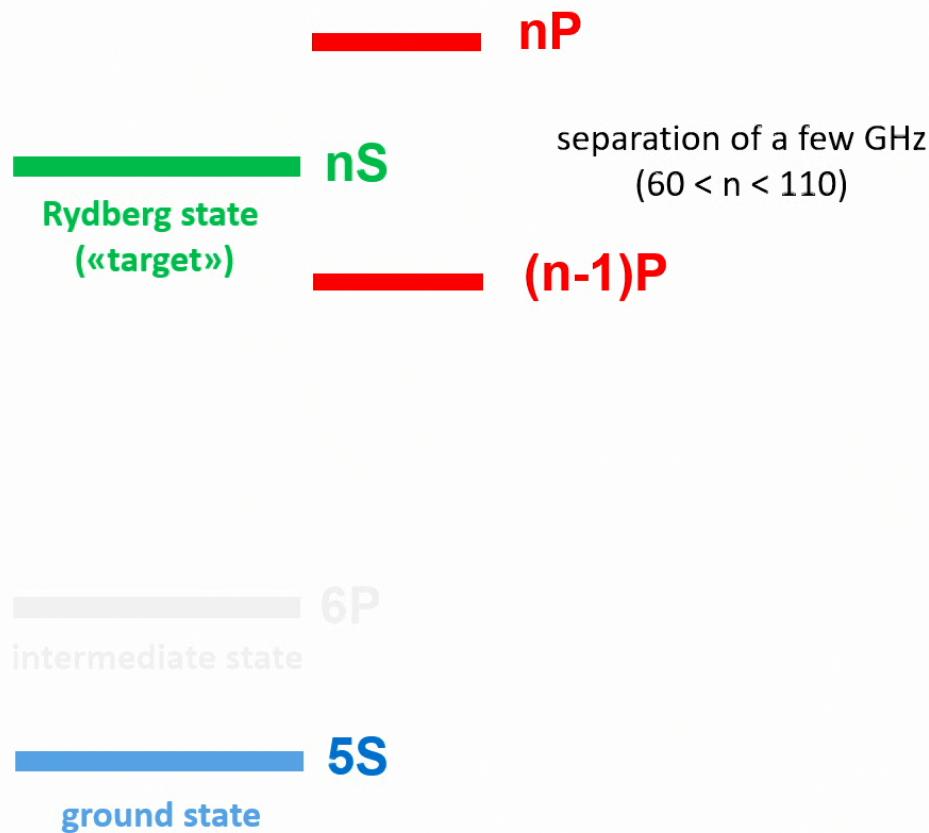
How «ideal» is our model?



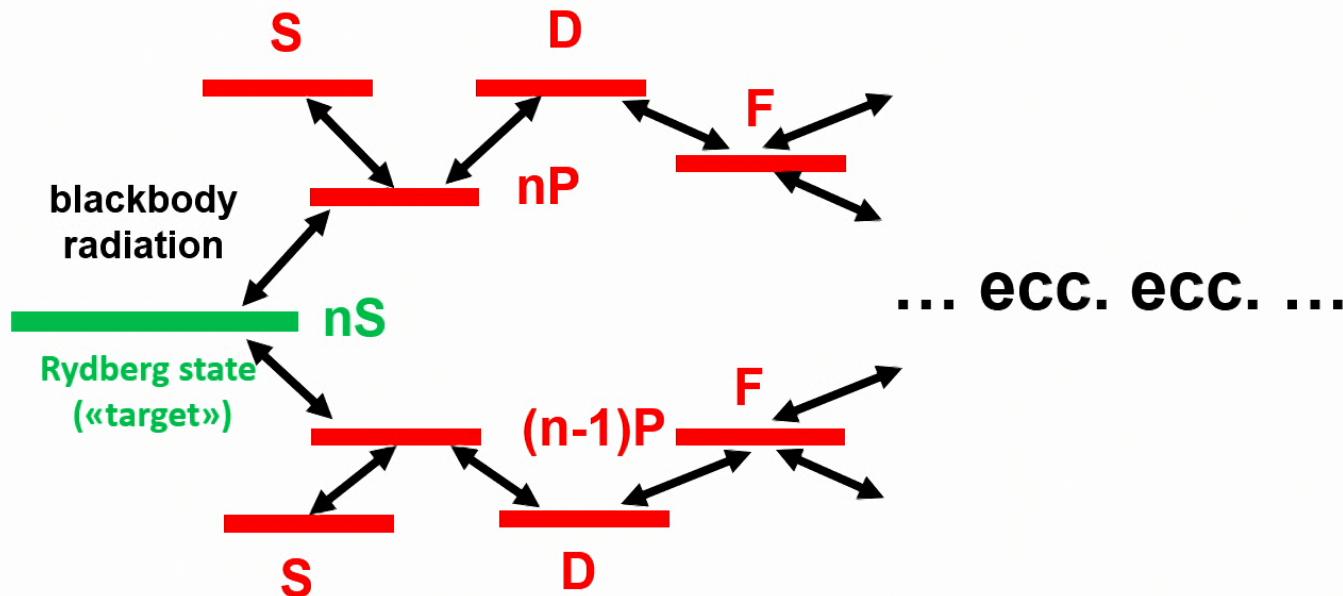
PHYSICAL REVIEW A 96, 041602(R) (2017)

Experimental signatures of an absorbing-state phase transition in an open driven many-body quantum system

How «ideal» is our model?



How «ideal» is our model?



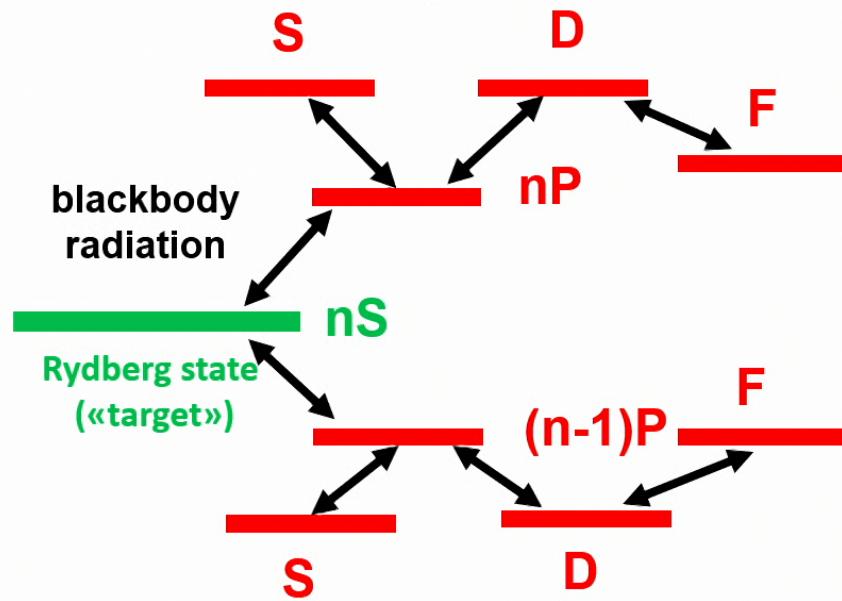
6P

intermediate state

5S

ground state

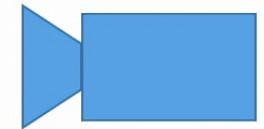
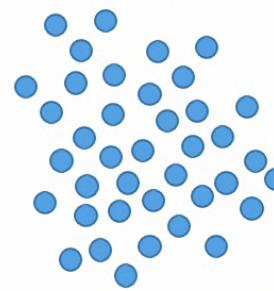
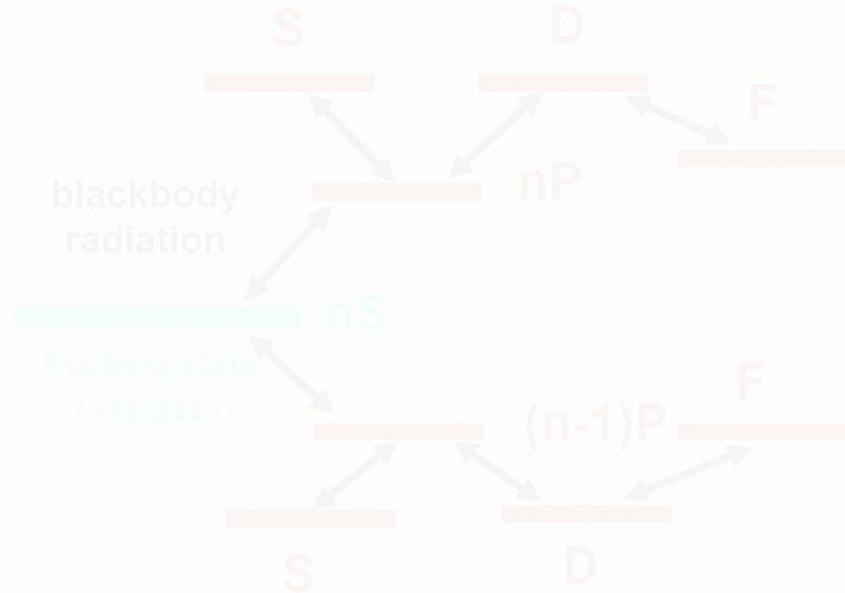
...not very! Now how can we measure this?



Rydberg state lifetime measurements

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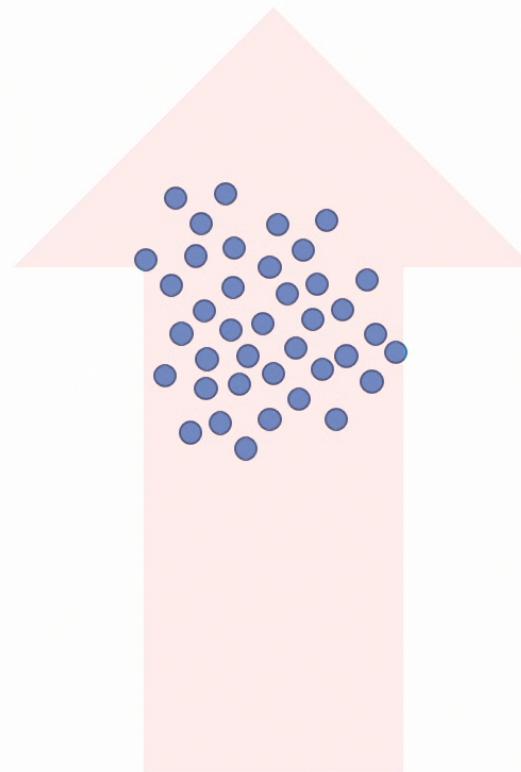
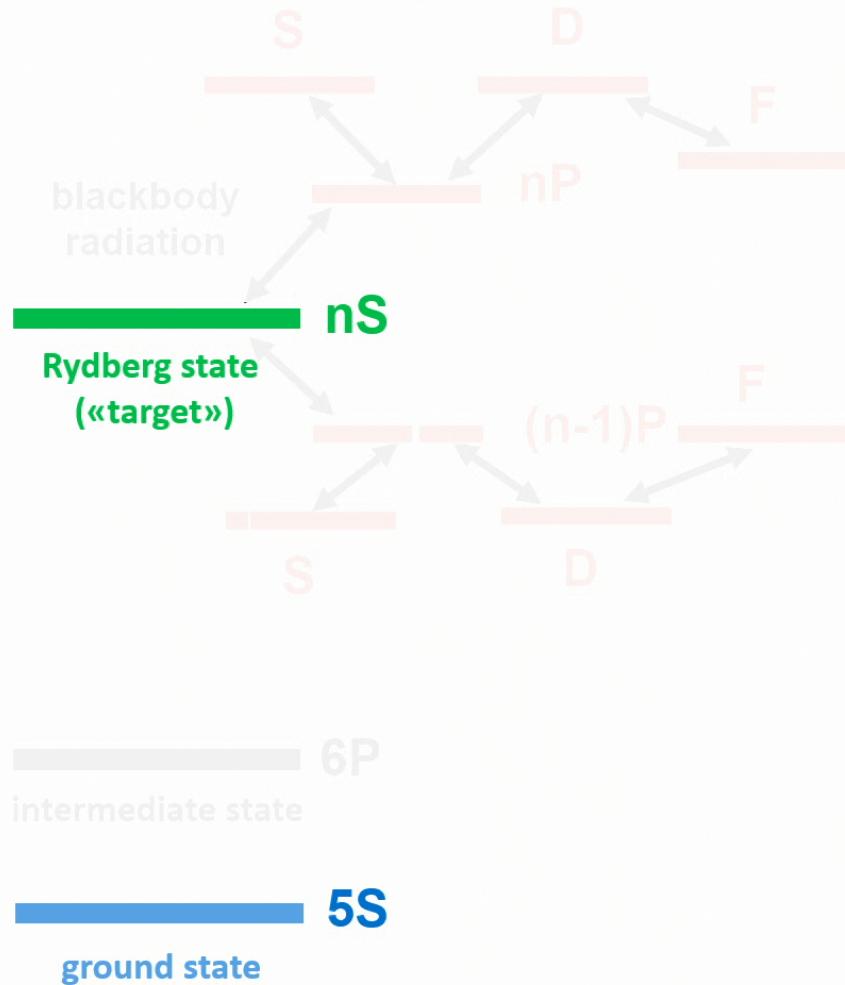
...not very! Now how can we measure this?



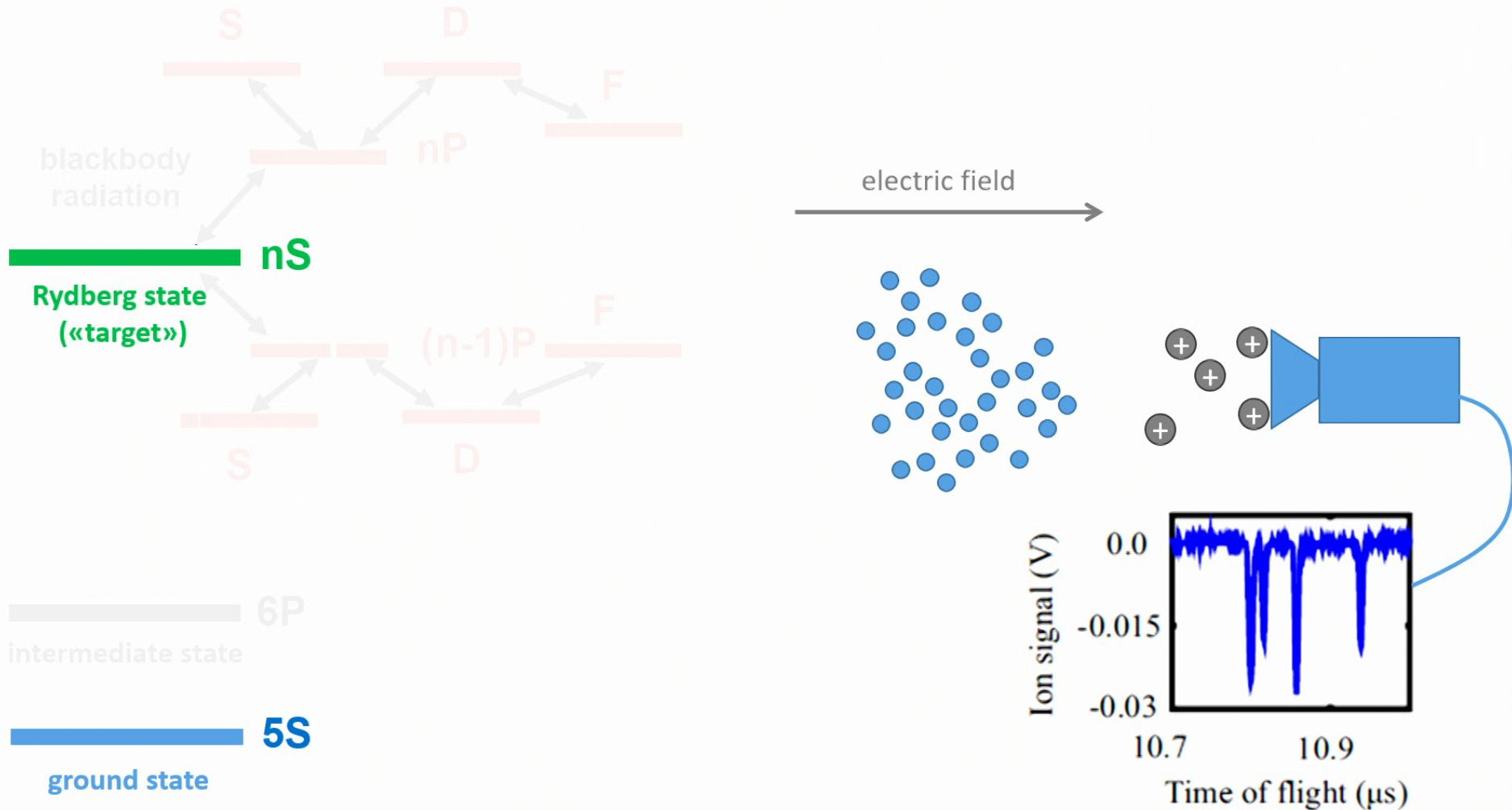
5S

ground state

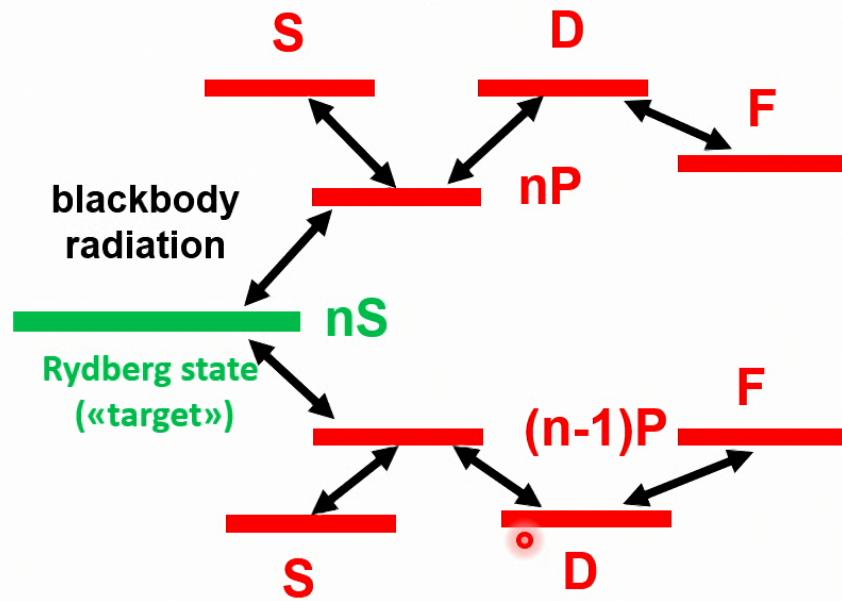
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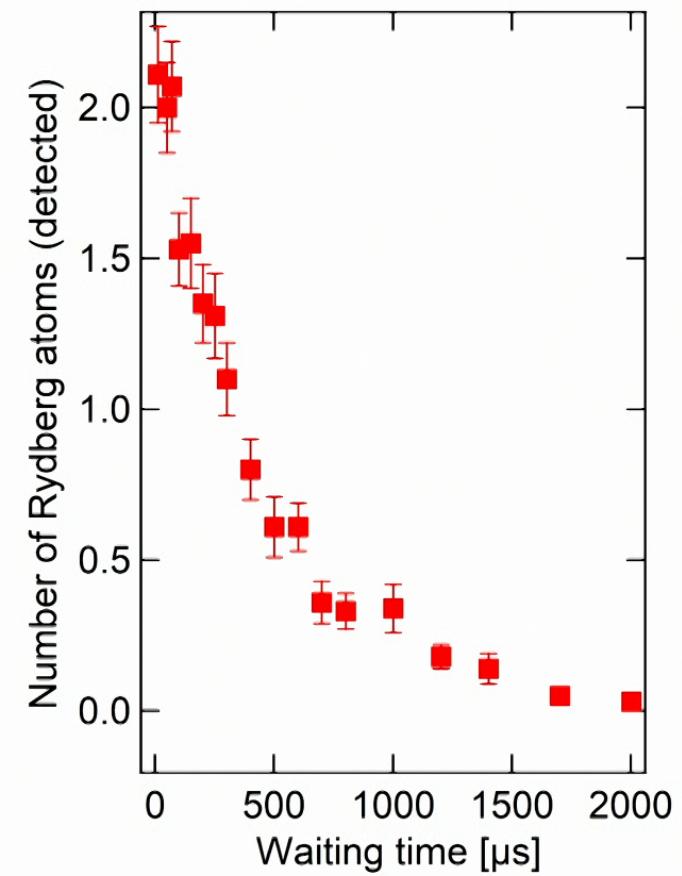
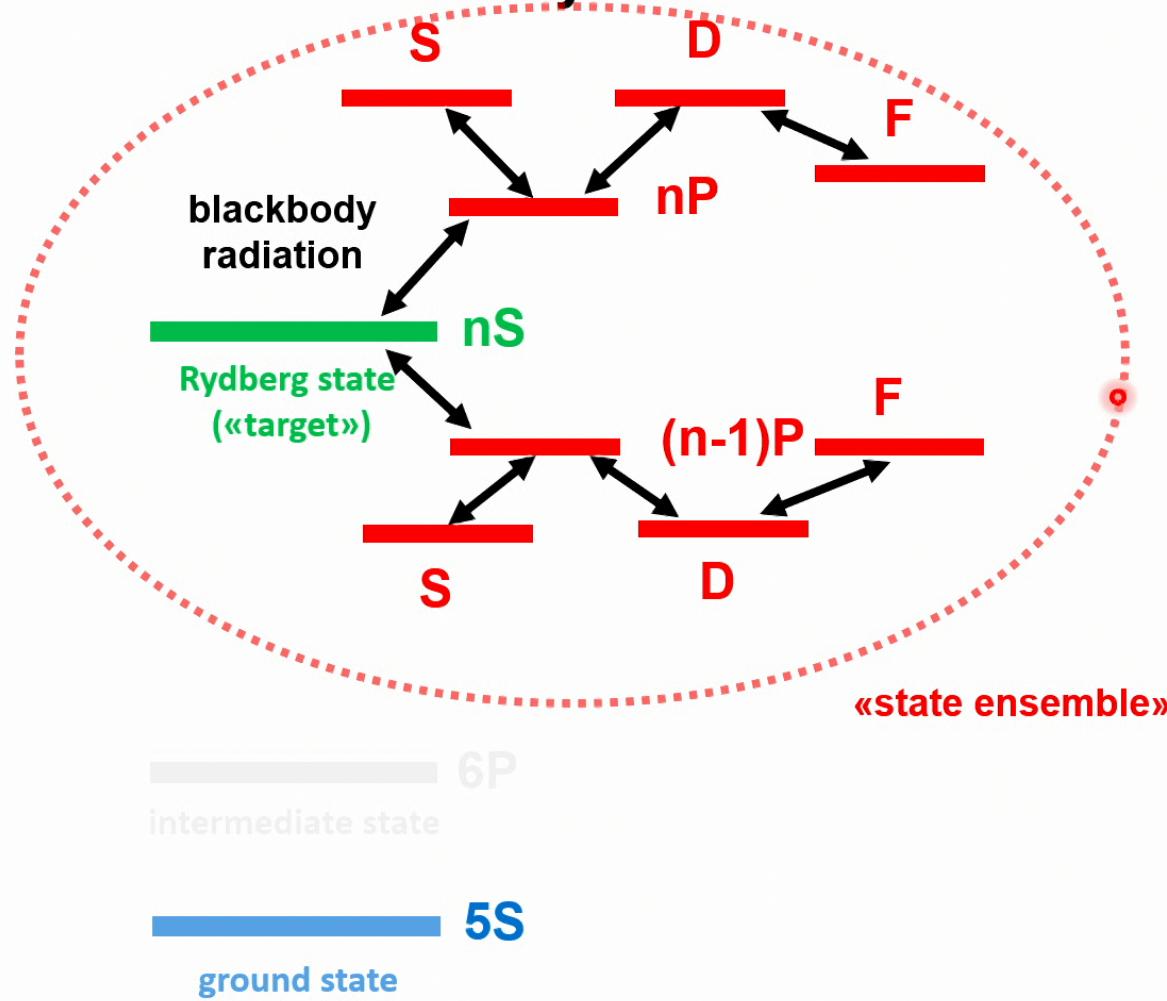
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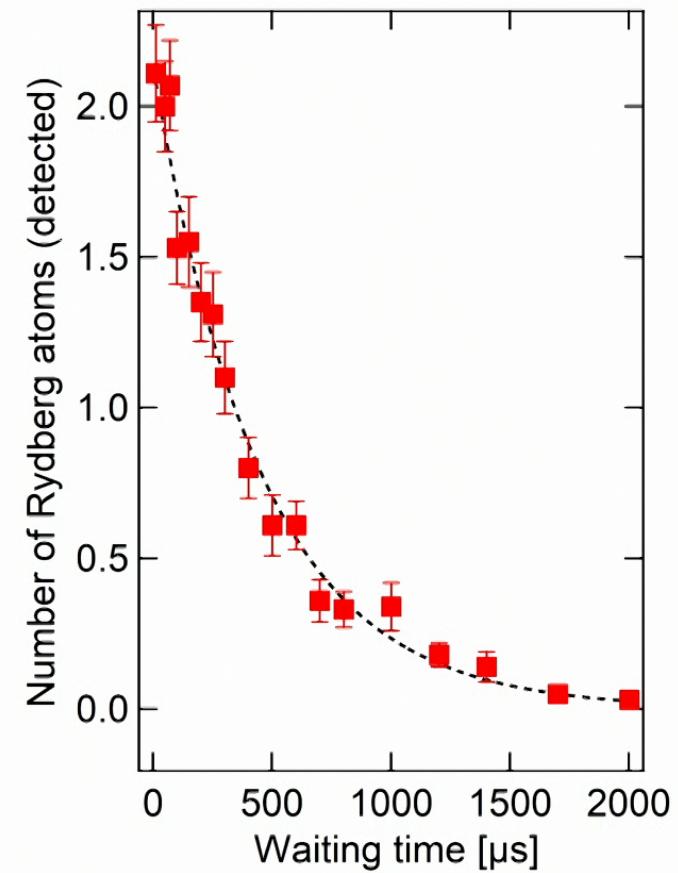
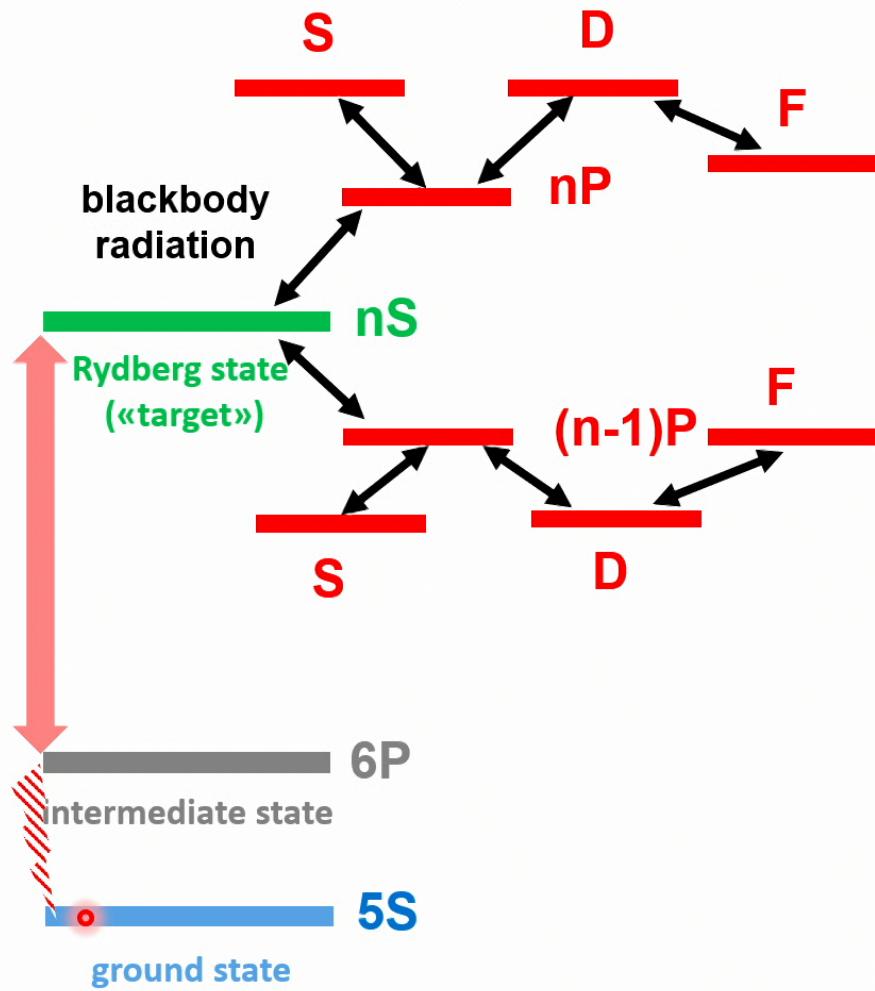
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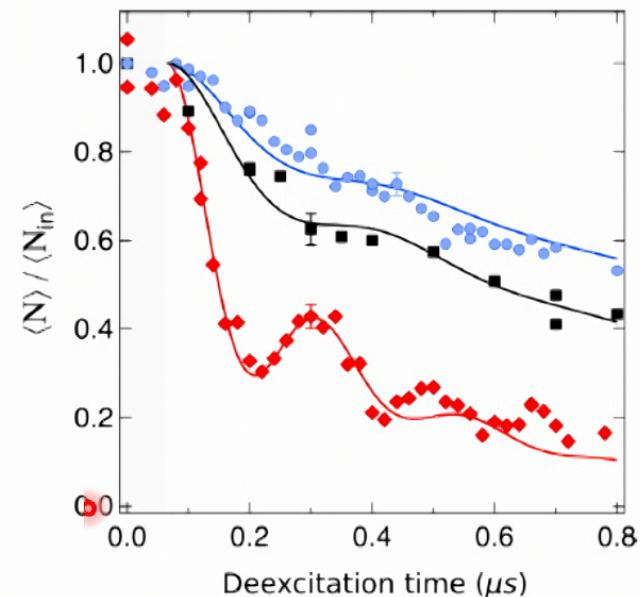
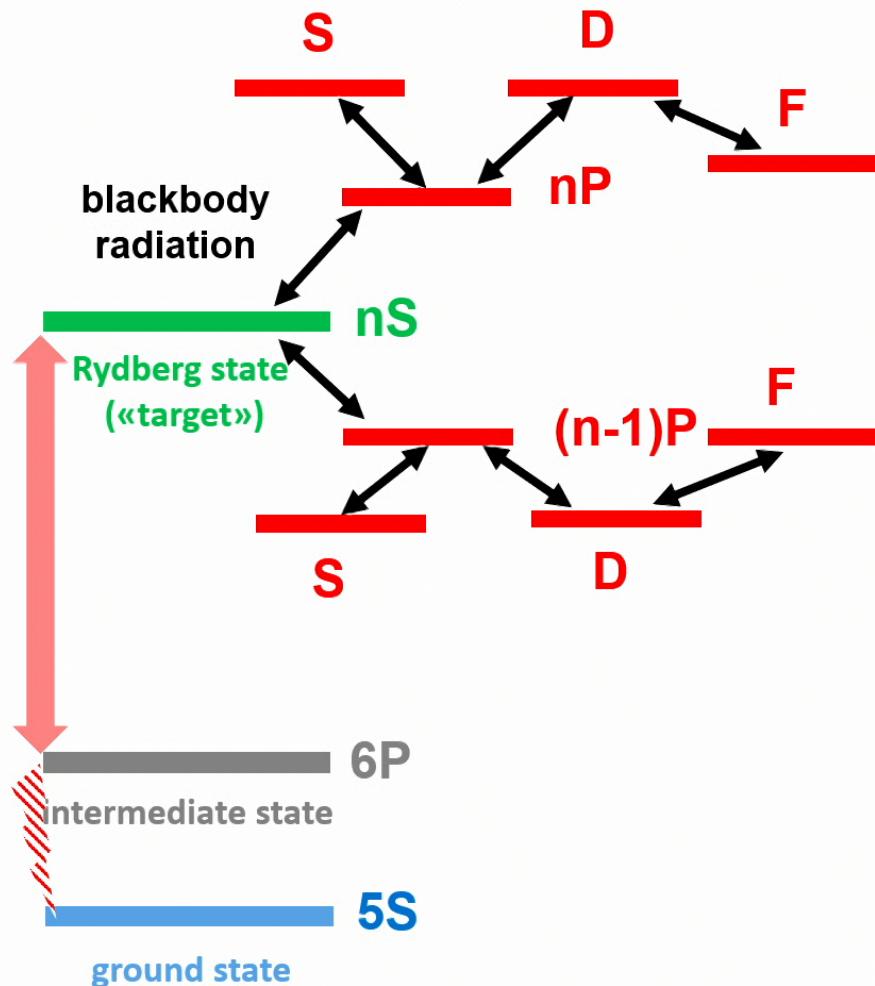
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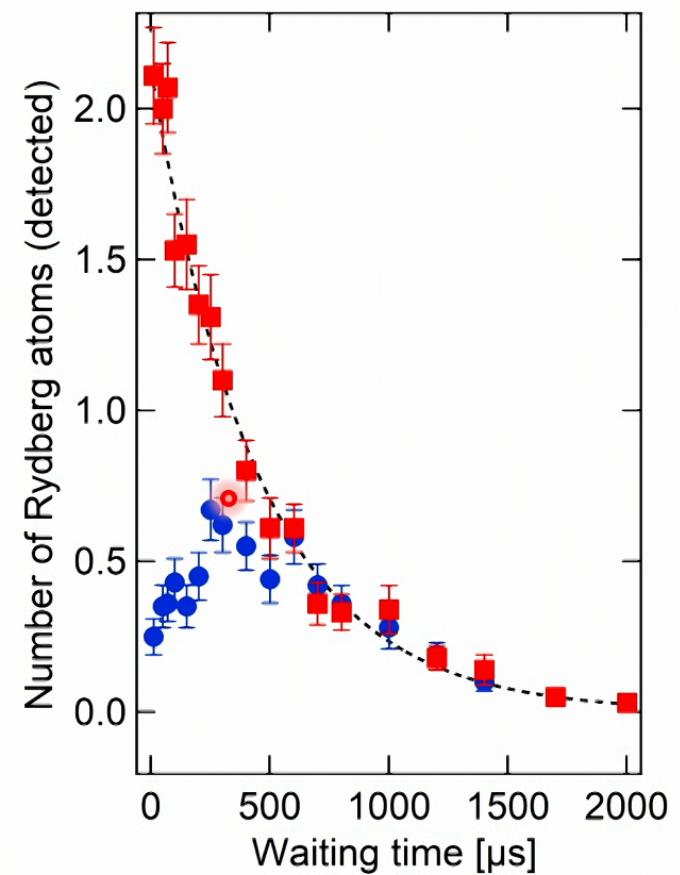
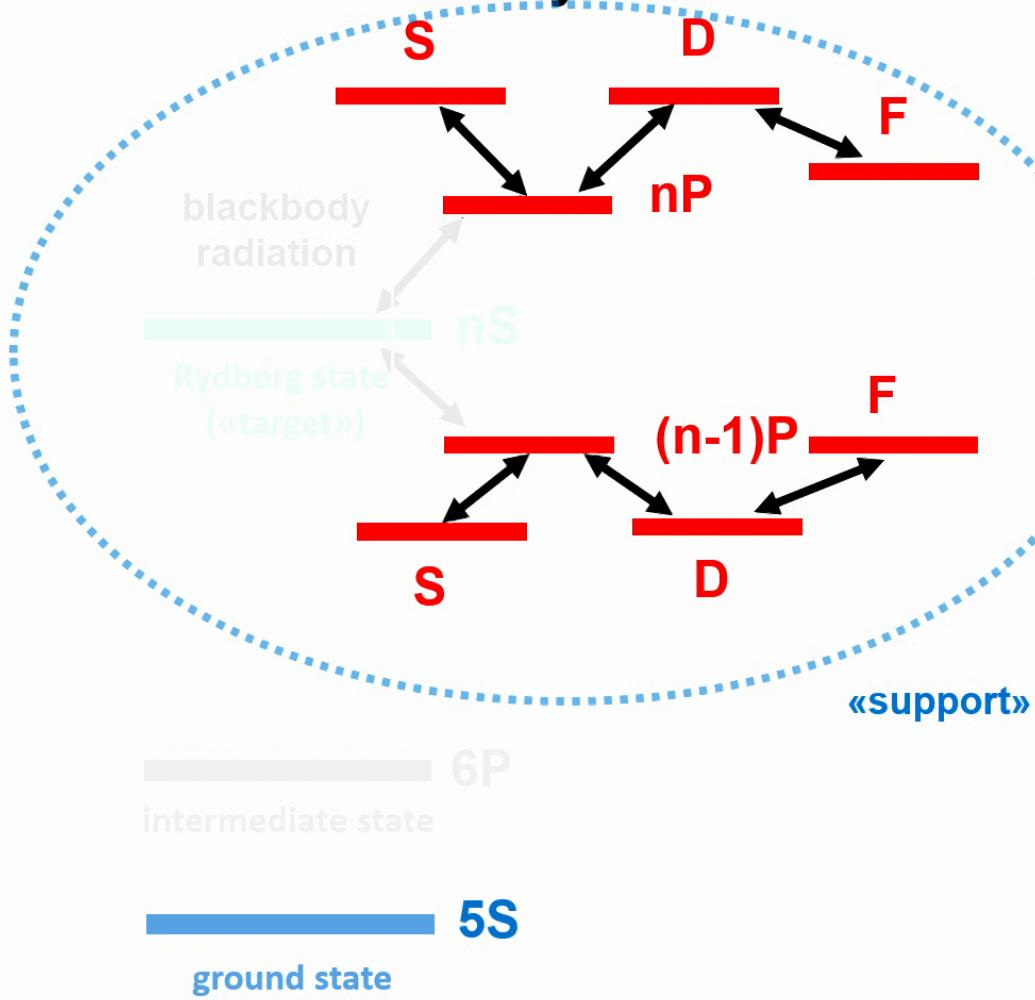
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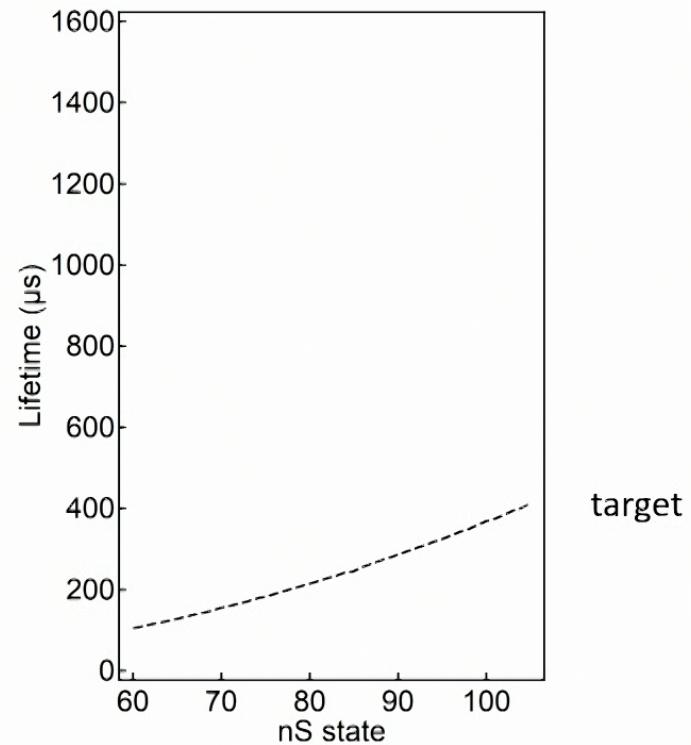
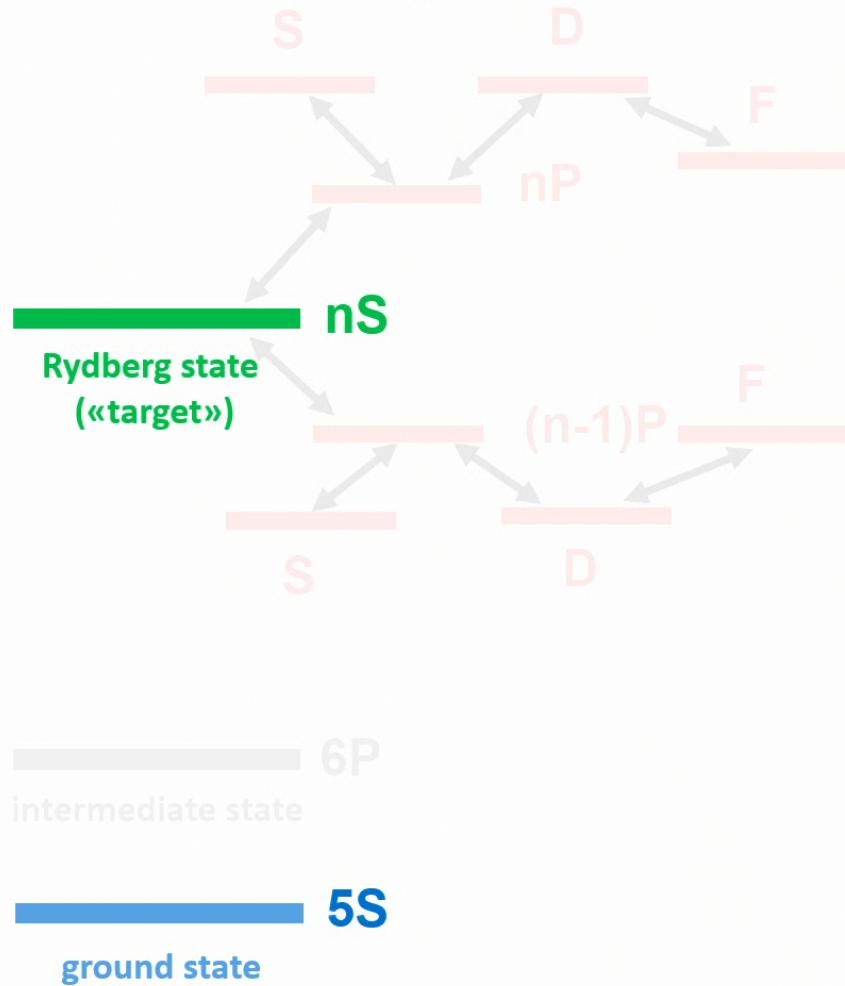
PHYSICAL REVIEW A 96, 043411 (2017)

Deexcitation spectroscopy of strongly interacting Rydberg gases

...not very! Now how can we measure this?

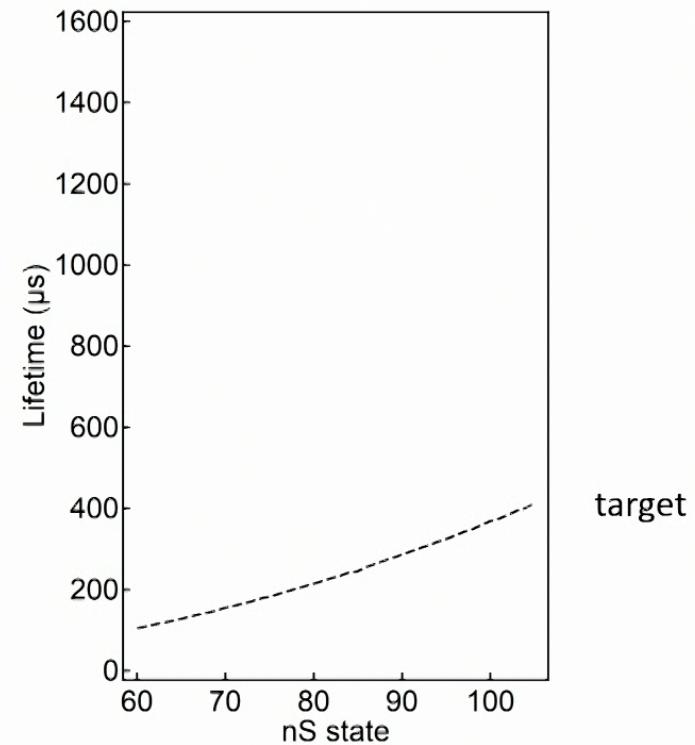
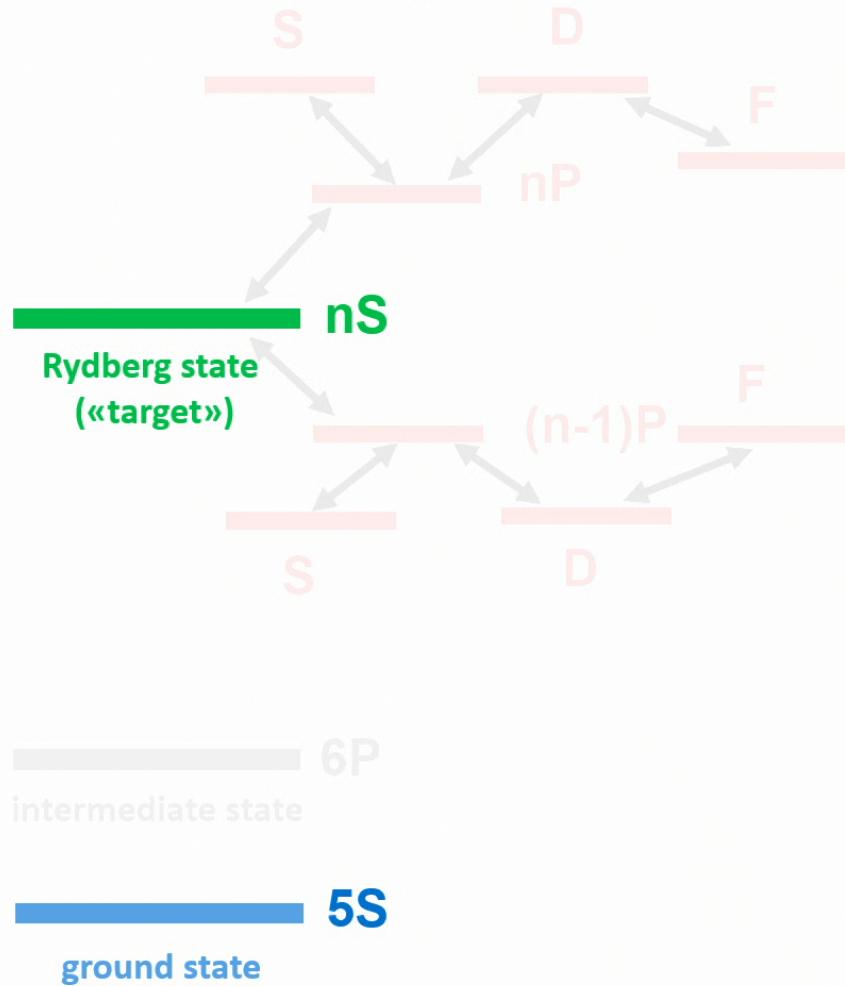


...not very! Now how can we measure this?



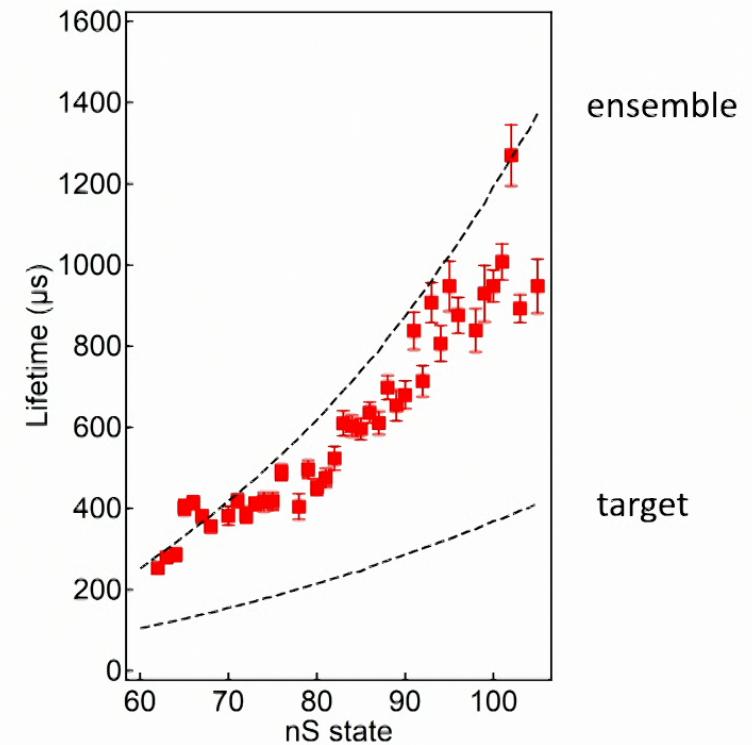
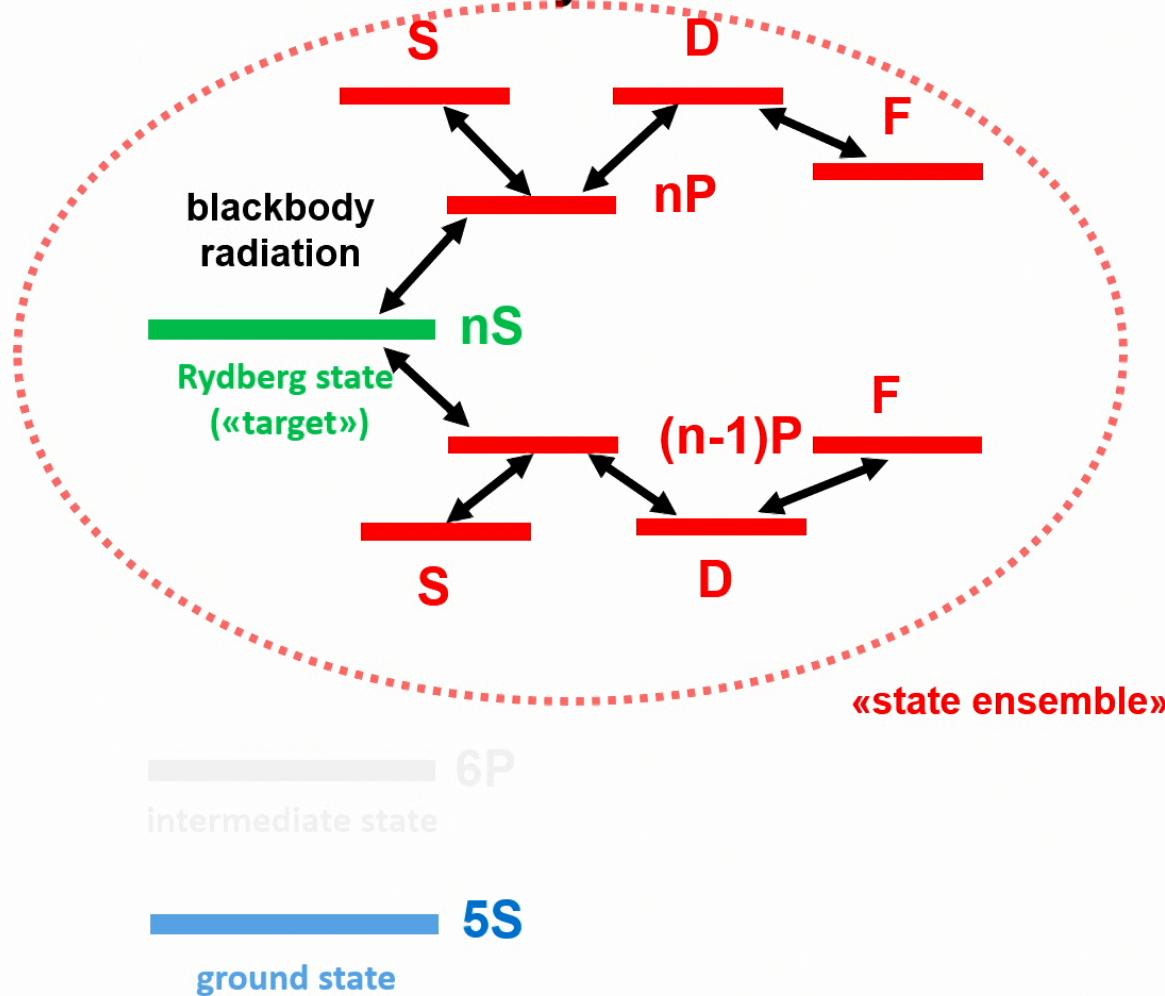
Calculate numerically taking into account all coupling up to F states (ARC open source library)

...not very! Now how can we measure this?

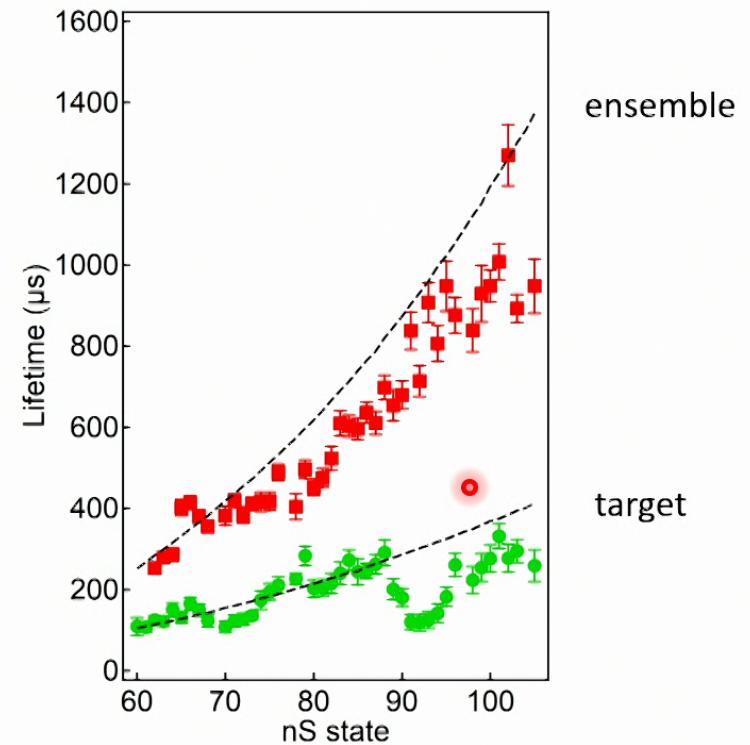
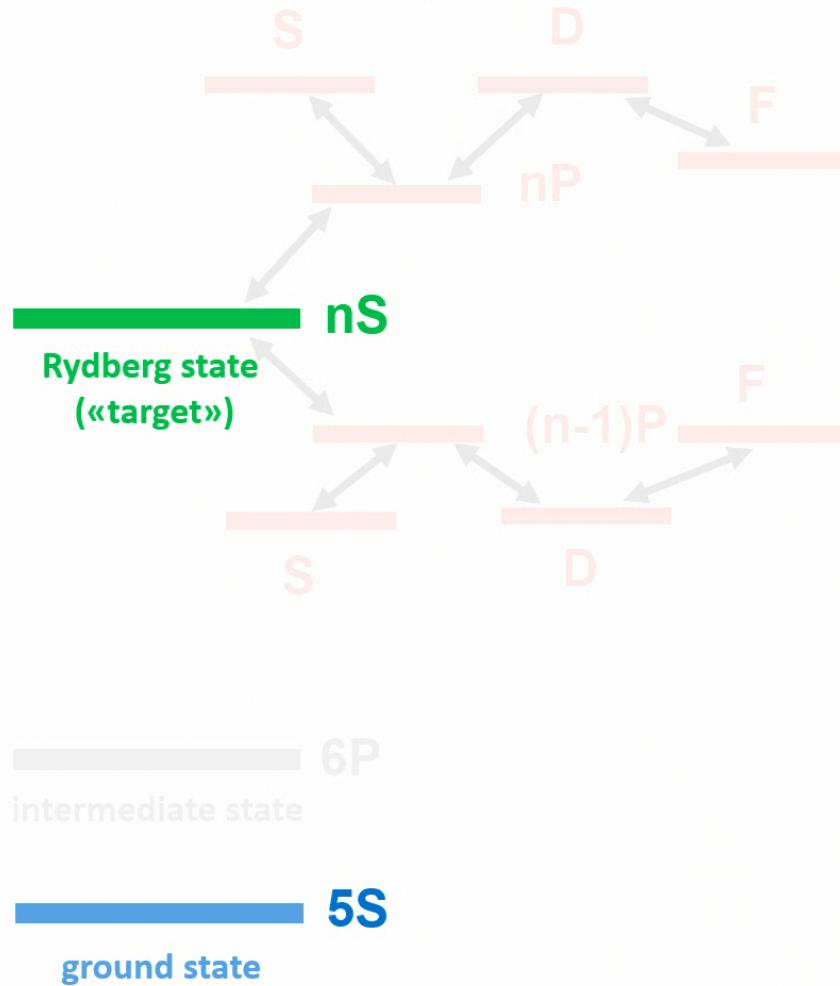


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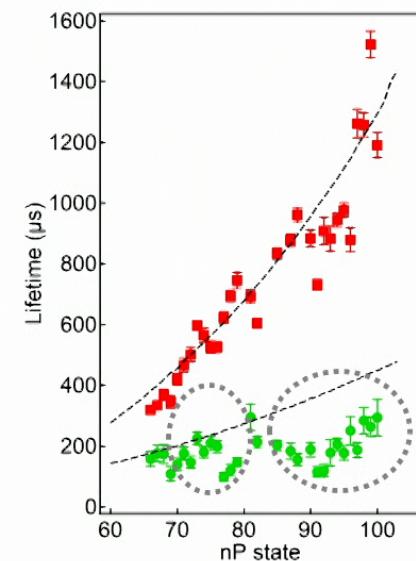
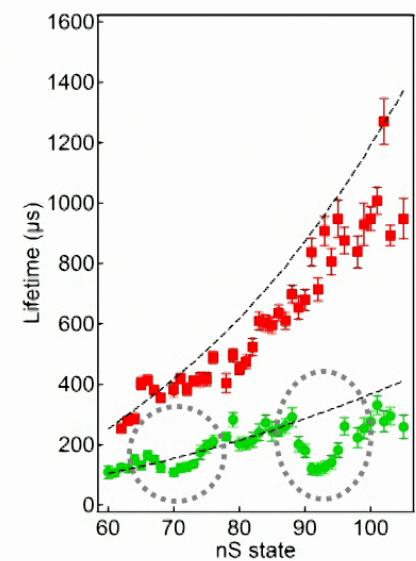
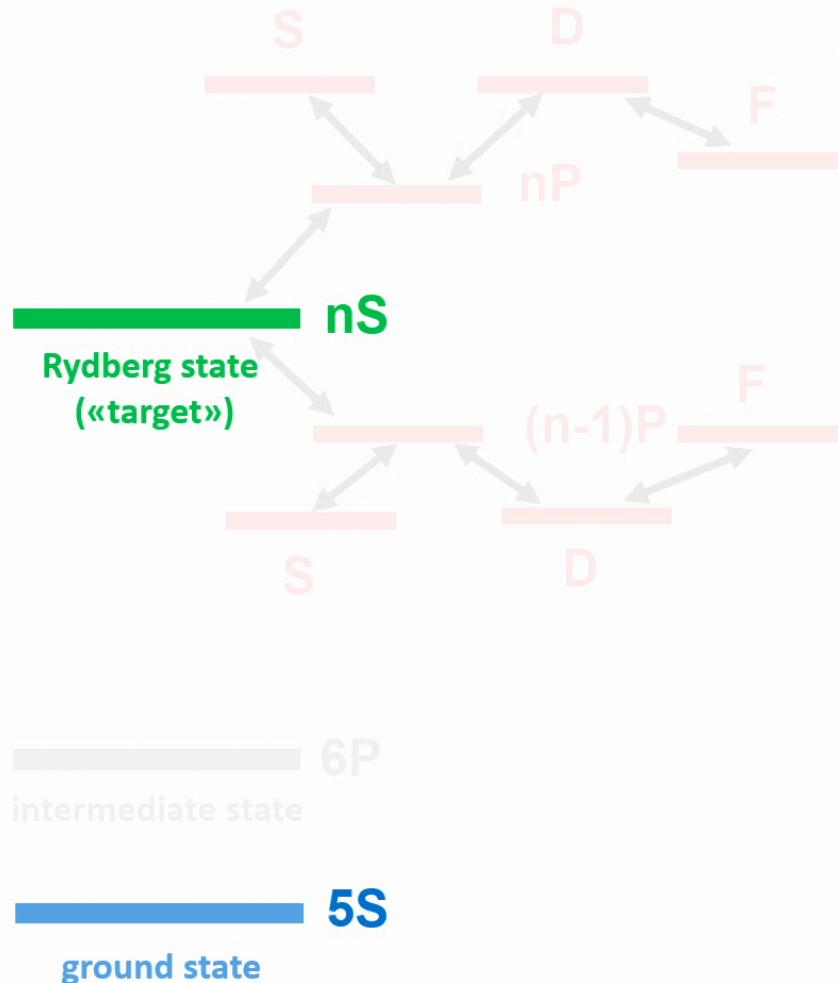
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...not very! Now how can we measure this?

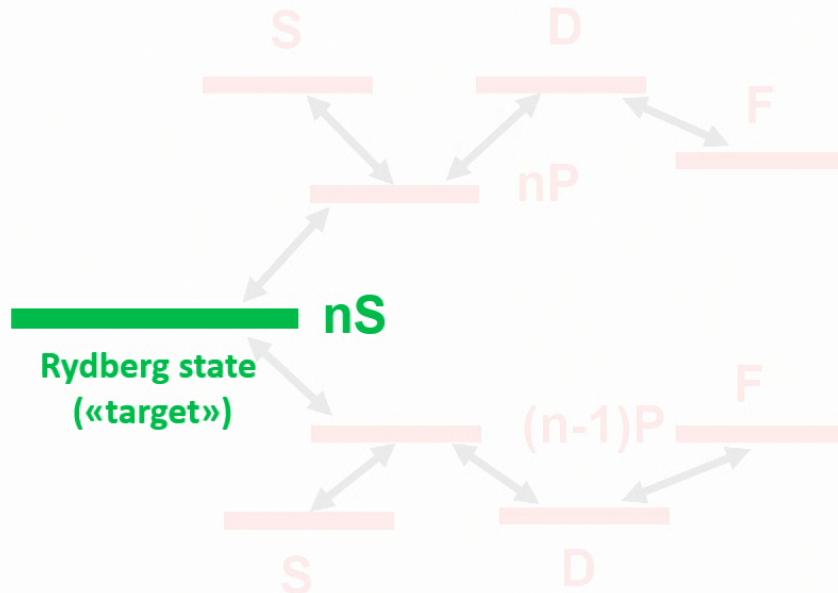


Large anomalies in the target lifetime – what's going on?



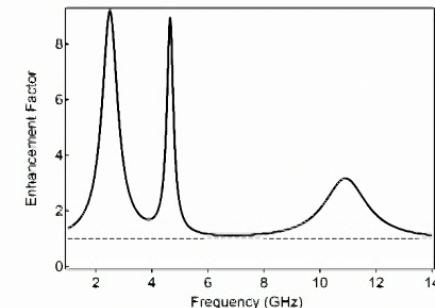
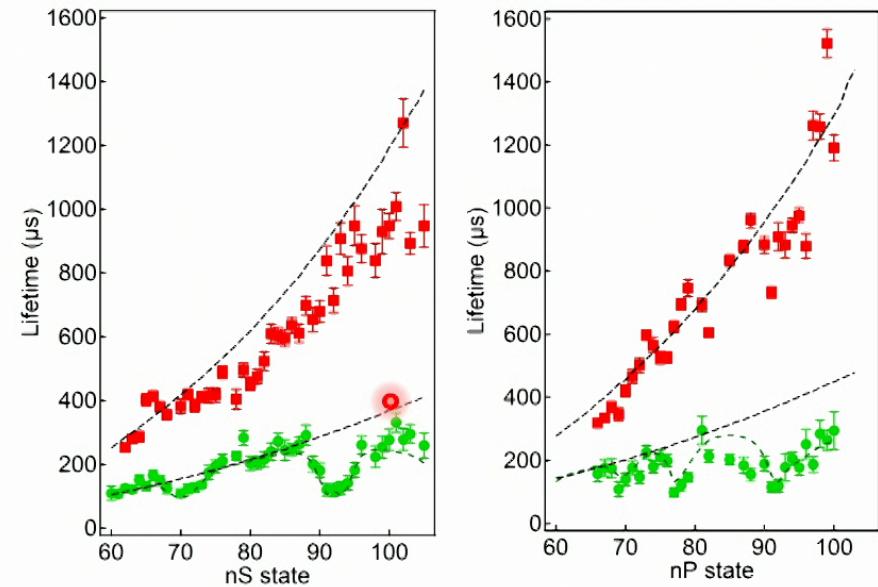
Clear anomalies in target state lifetimes

Is it just background microwave radiation...

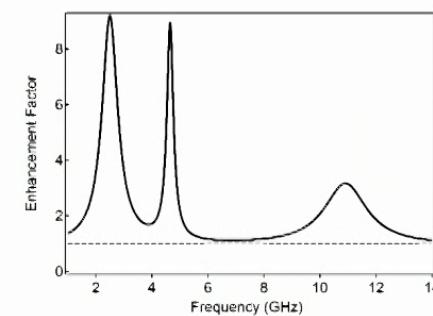
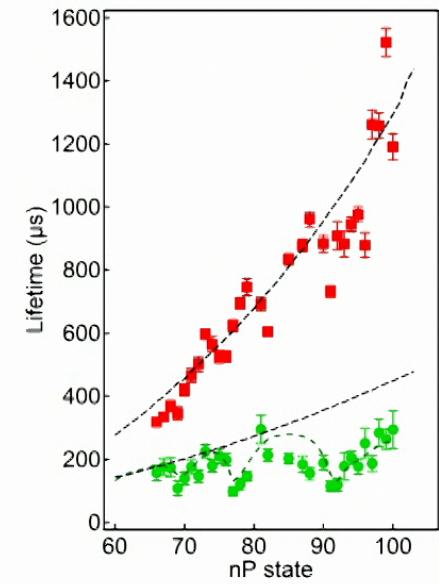
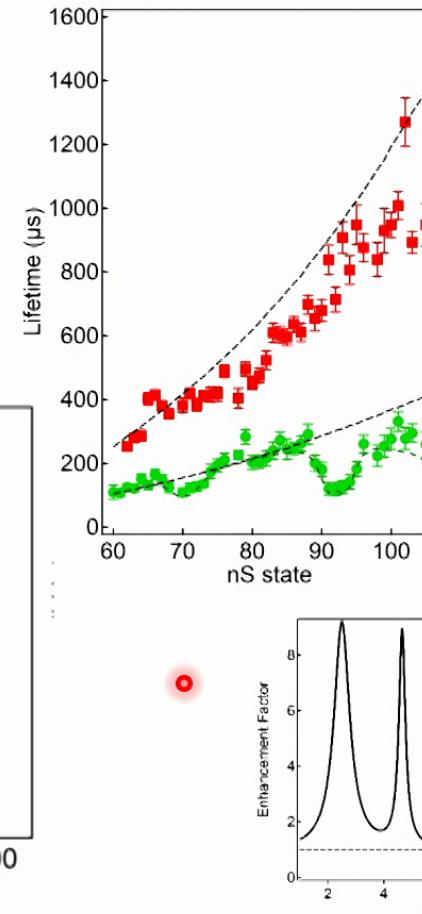
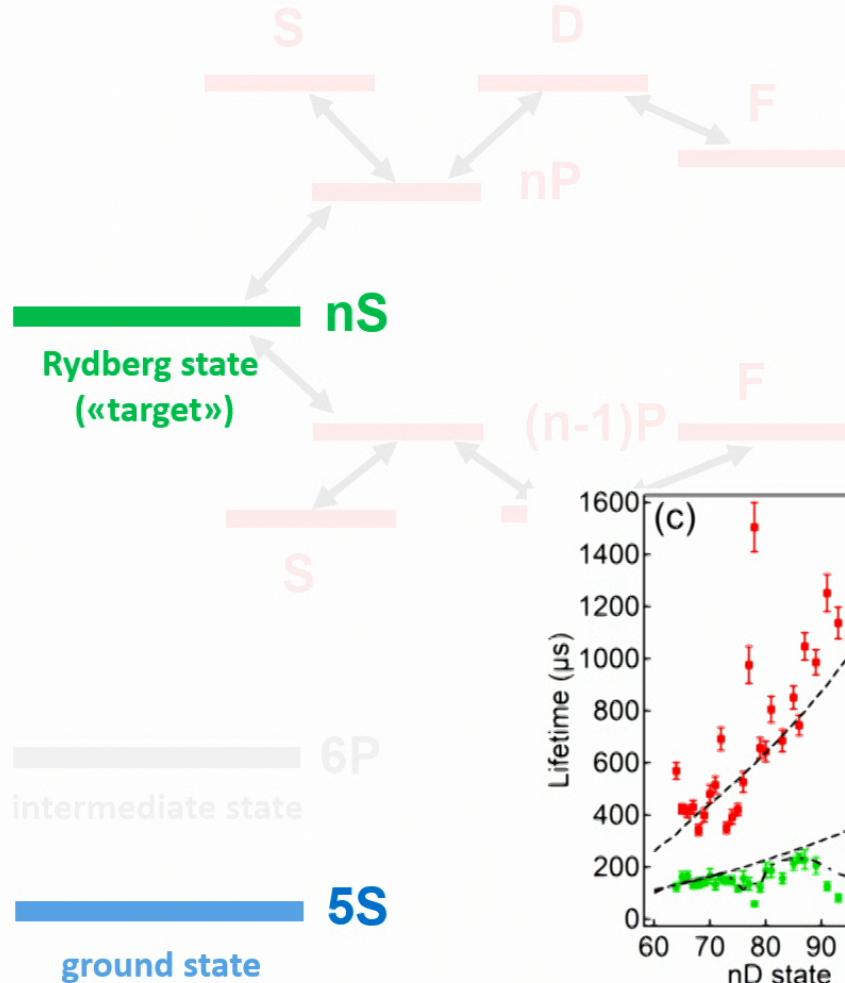


6P
intermediate state

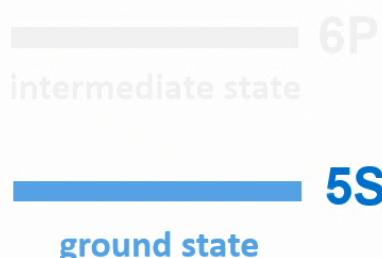
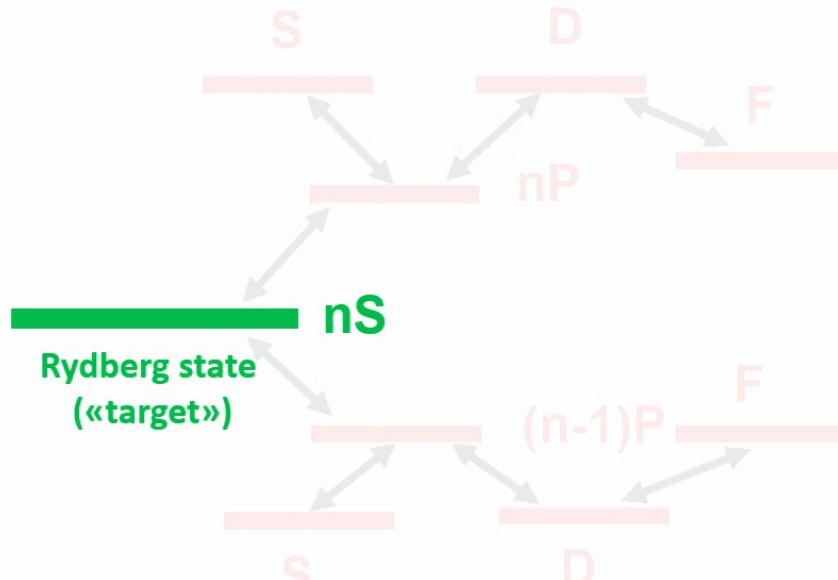
5S
ground state



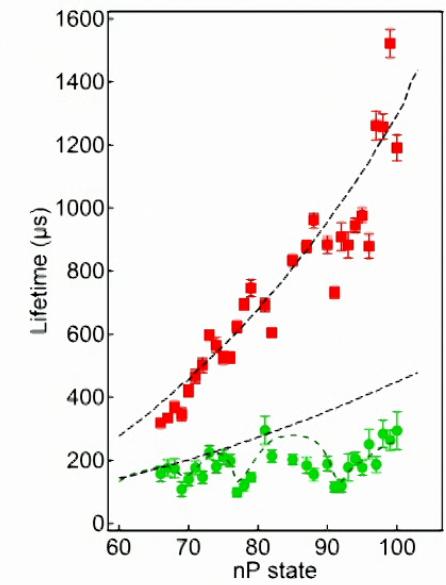
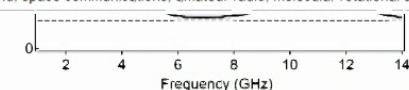
Is it just background microwave radiation...



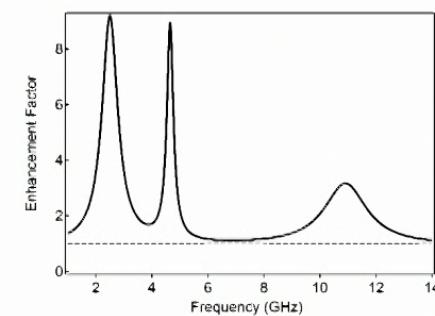
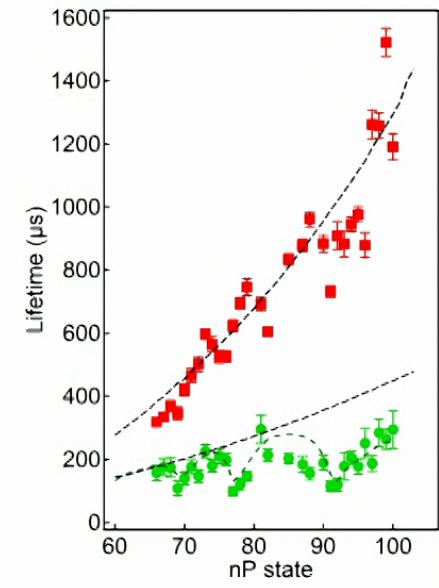
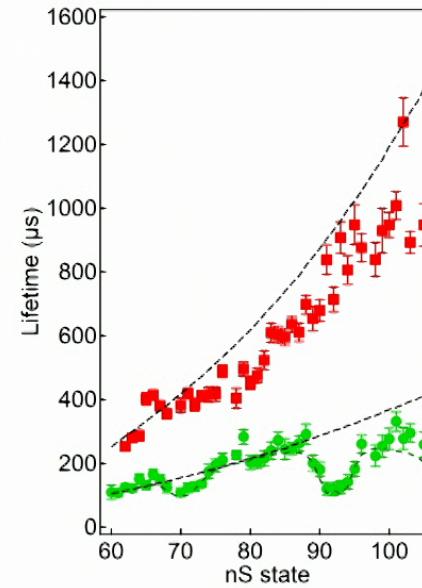
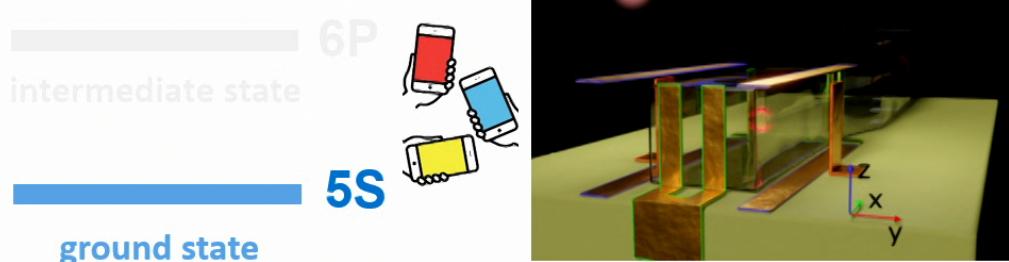
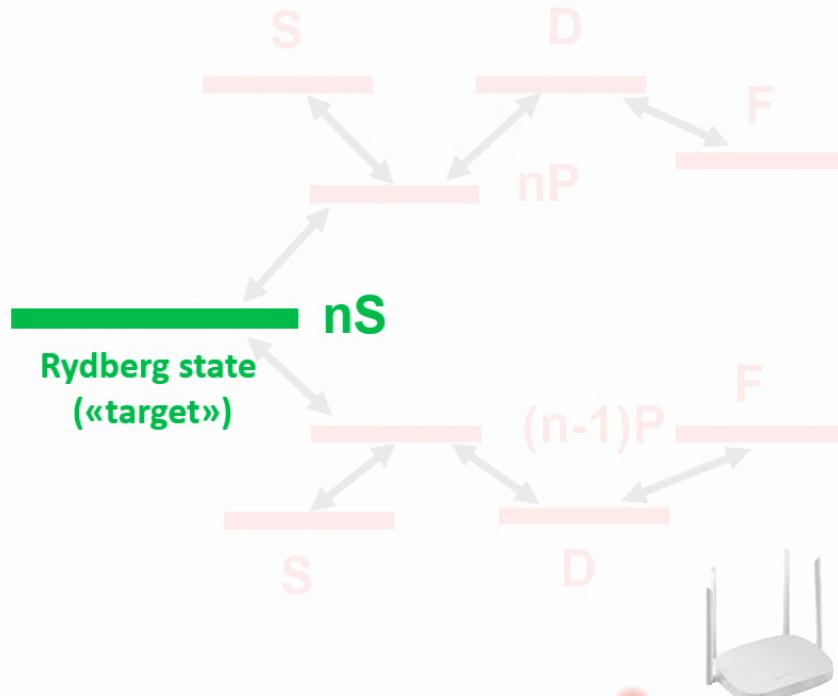
Is it just background microwave radiation...



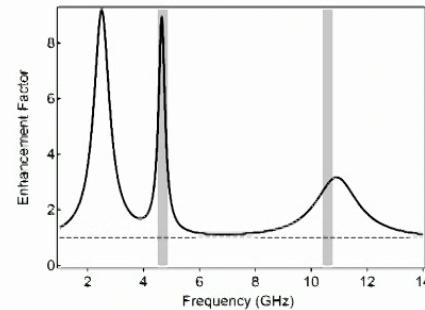
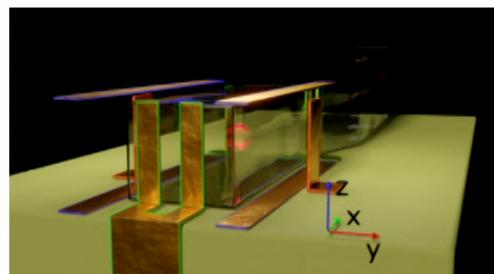
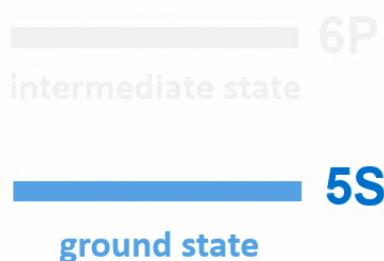
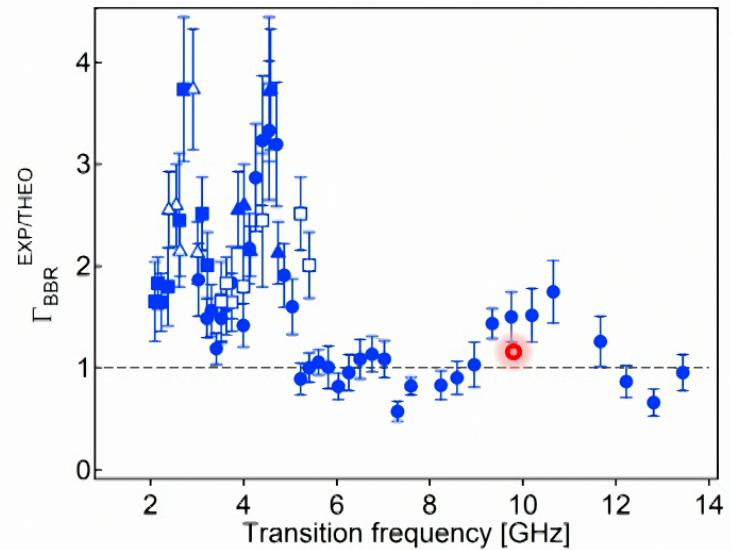
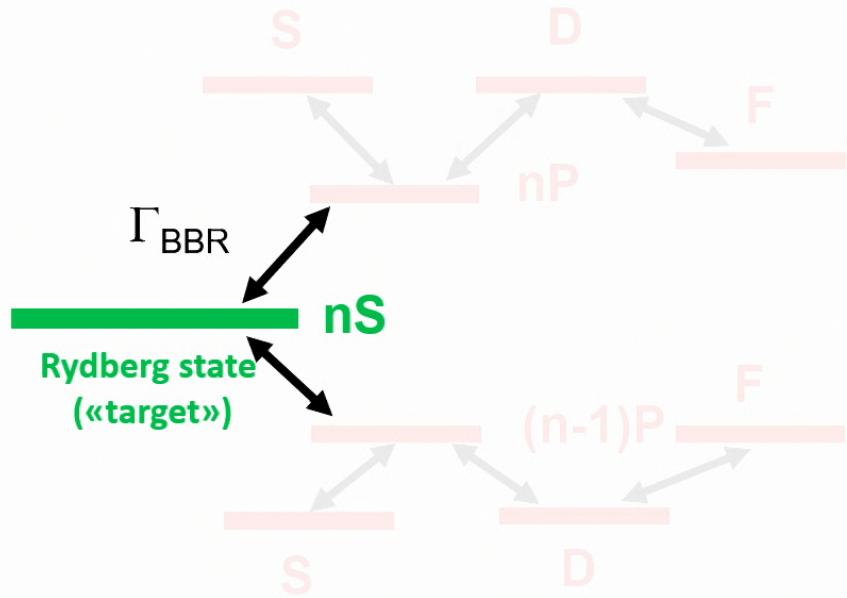
Designation	Frequency range	Wavelength range	Typical uses
L band	1 to 2 GHz	15 cm to 30 cm	military telemetry, GPS, mobile phones (GSM), amateur radio
S band	2 to 4 GHz	7.5 cm to 15 cm	weather radar, surface ship radar, some communications satellites, microwave ovens, microwave devices/communications, radio astronomy, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS, amateur radio
C band	4 to 8 GHz	3.75 cm to 7.5 cm	long-distance radio telecommunications
X band	8 to 12 GHz	25 mm to 37.5 mm	satellite communications, radar, terrestrial broadband, space communications, amateur radio, molecular rotational spectroscopy



Is it just background microwave radiation...

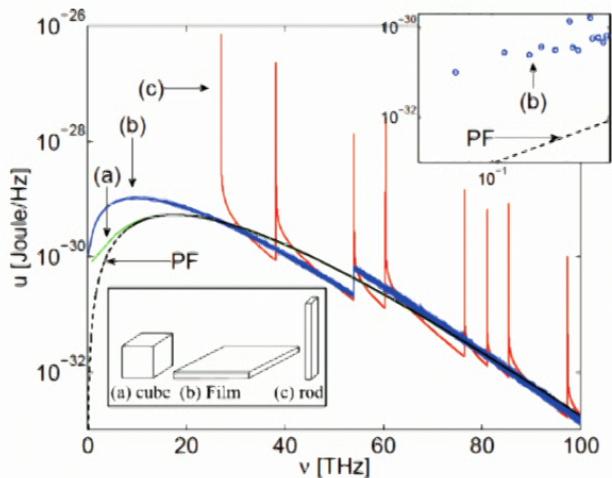
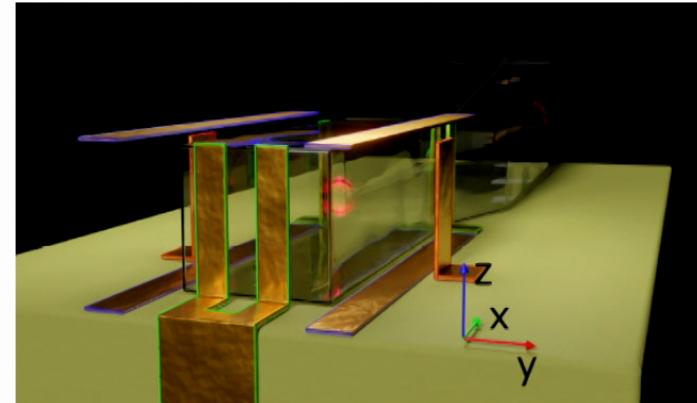
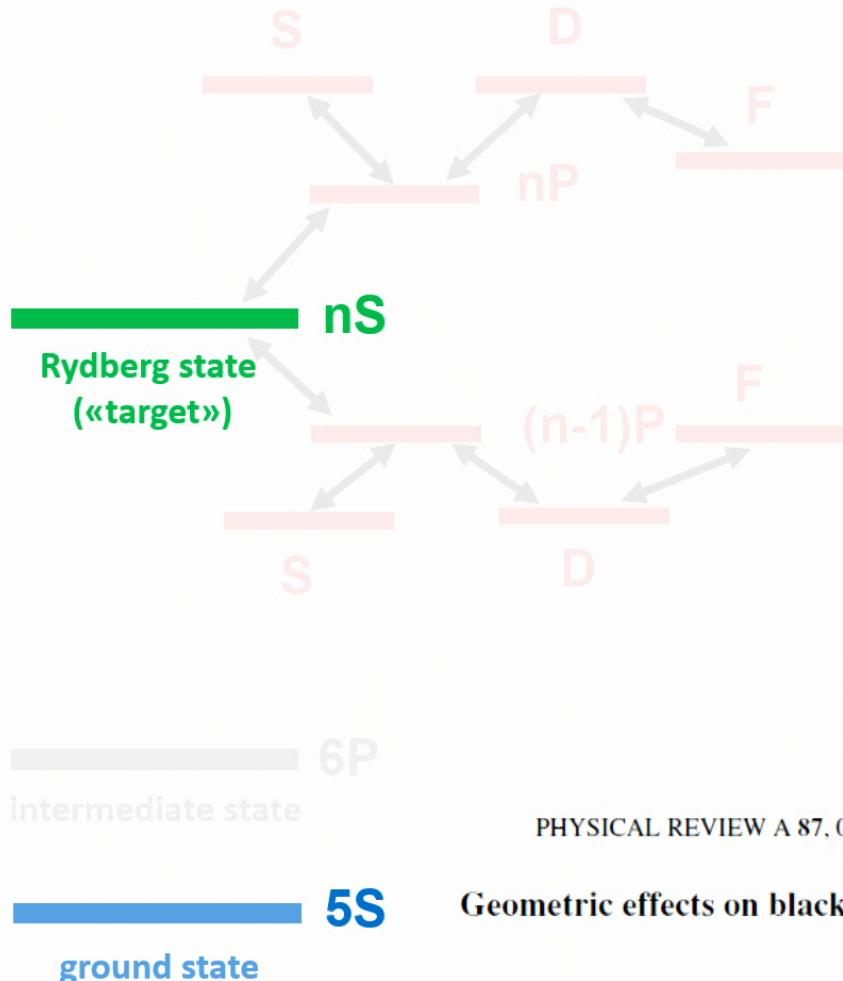


...or could it be the geometry...?



Lowest resonant microwave modes

...or could it be the geometry...?



Brief aside: the «pros» of knowing your literature...

VOLUME 49, NUMBER 2

PHYSICAL REVIEW LETTERS

12 JULY 1982

**Collective Absorption of Blackbody Radiation by Rydberg Atoms in a Cavity:
An Experiment on Bose Statistics and Brownian Motion**

J. M. Raimond, P. Goy, M. Gross, C. Fabre, and S. Haroche

VOLUME 81, NUMBER 13

PHYSICAL REVIEW LETTERS

28 SEPTEMBER 1998

Blackbody Excitation of an Atom Controlled by a Tunable Cavity

K. S. Lai* and E. A. Hinds

VOLUME 55, NUMBER 20

PHYSICAL REVIEW LETTERS

11 NOVEMBER 1985

Inhibited Spontaneous Emission by a Rydberg Atom

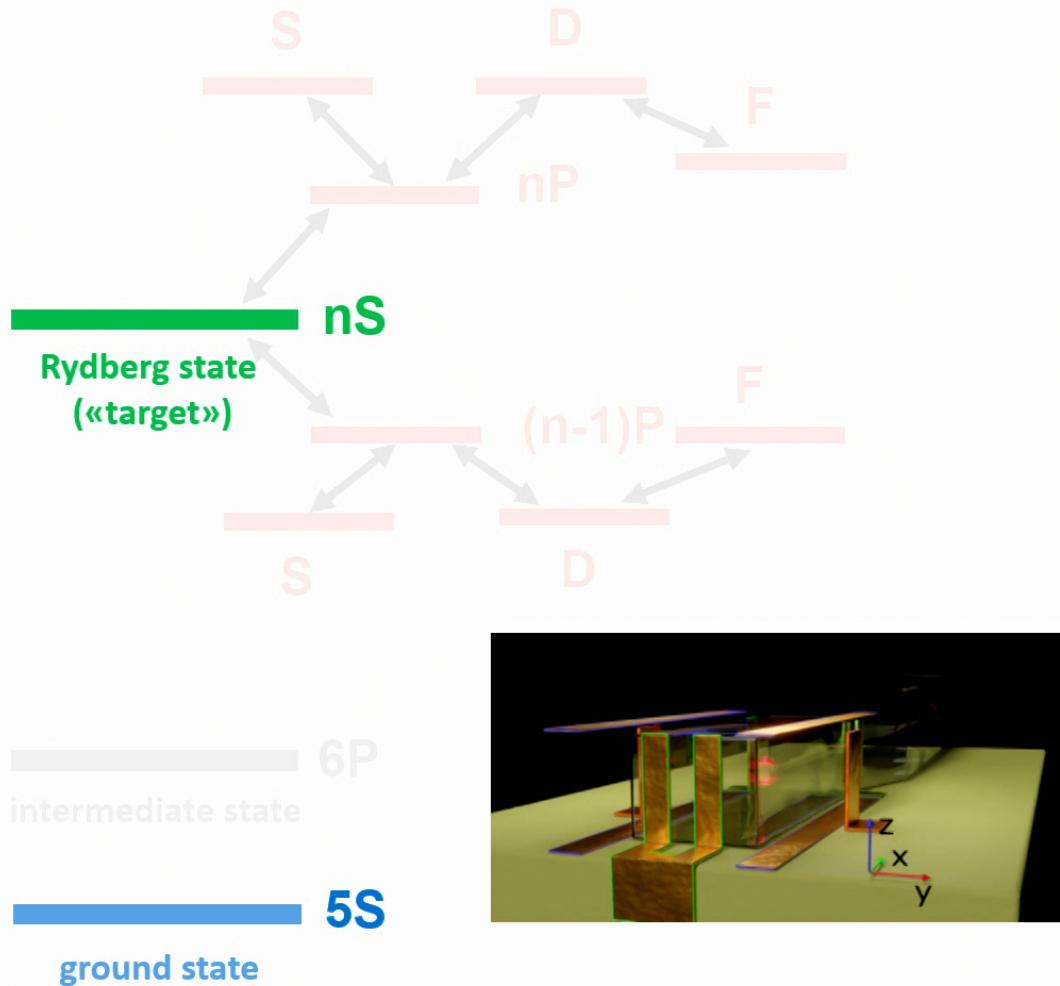
Randall G. Hulet,^(a) Eric S. Hilfer, and Daniel Kleppner

PHYSICAL REVIEW A 92, 012517 (2015)

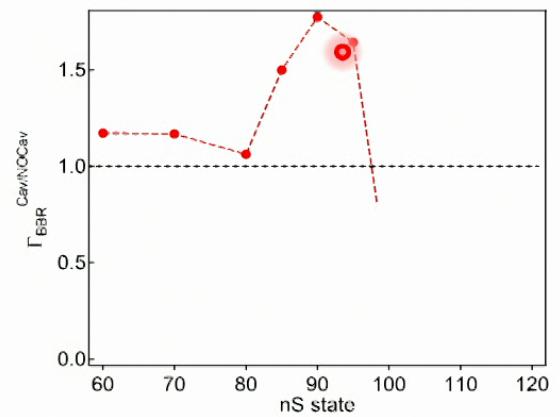
All-optical measurement of Rydberg-state lifetimes

Markus Mack,^{*} Jens Grimmel, Florian Karlewski, Lőrinc Sárkány, Helge Hattermann, and József Fortágh[†]

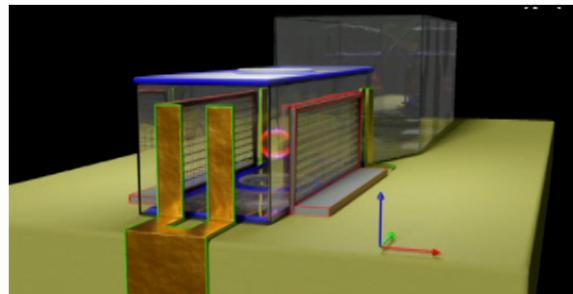
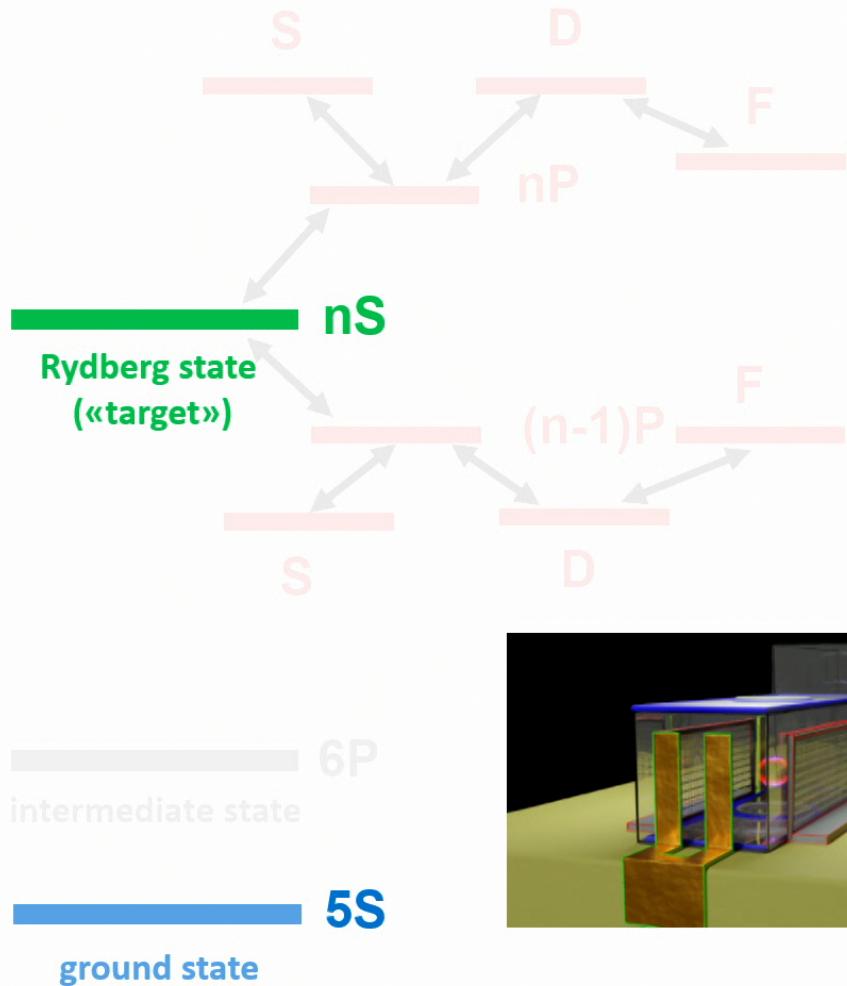
...or could it be the geometry...?



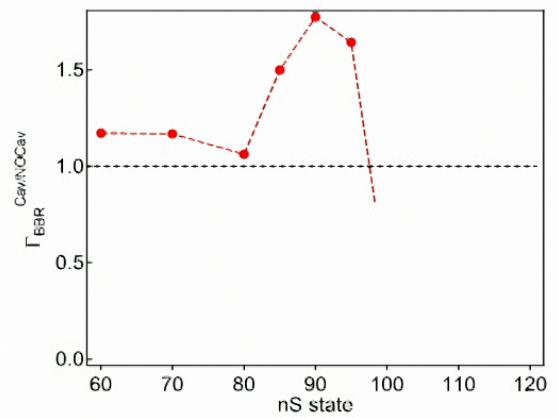
Count the modes in the cavity (cell) and compare to Planck's formula



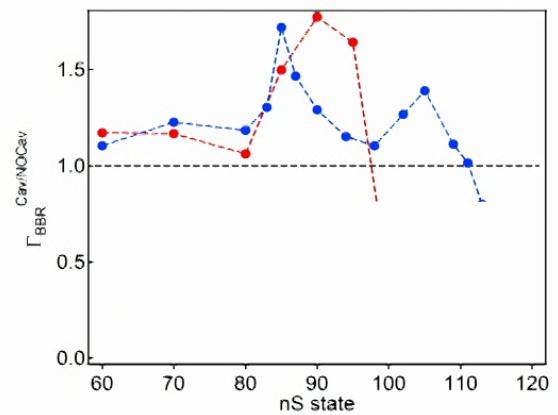
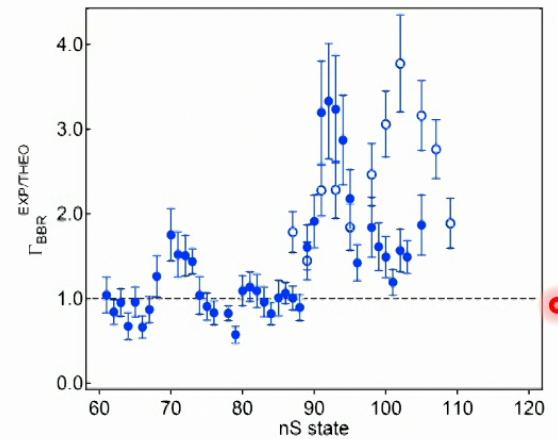
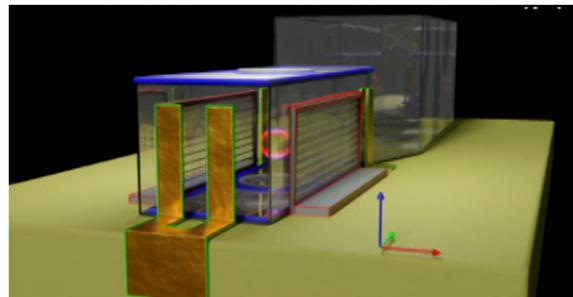
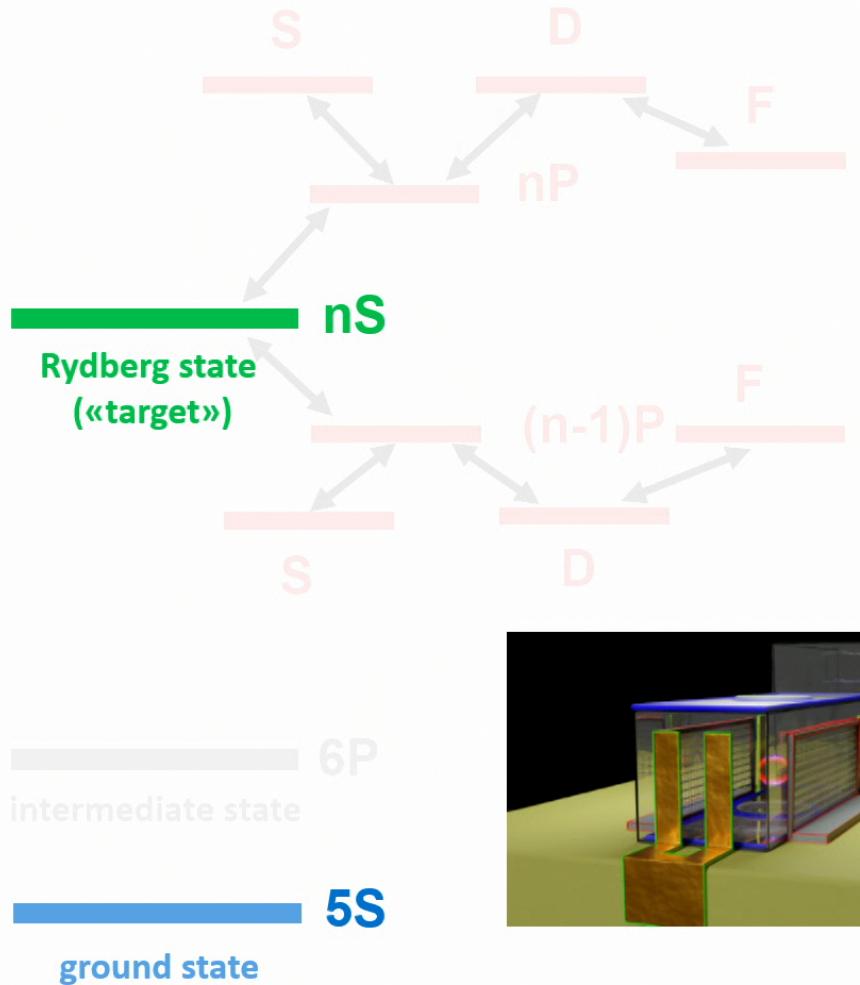
...or could it be the geometry...?



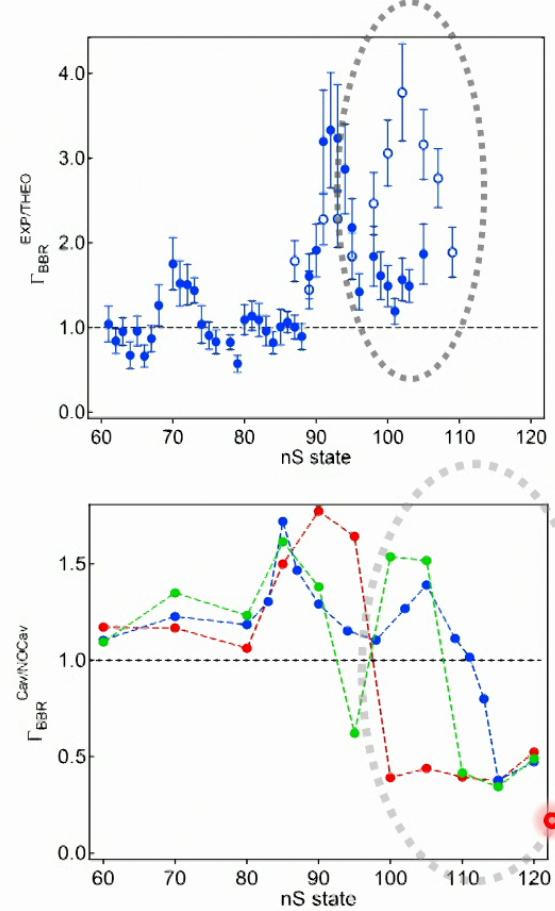
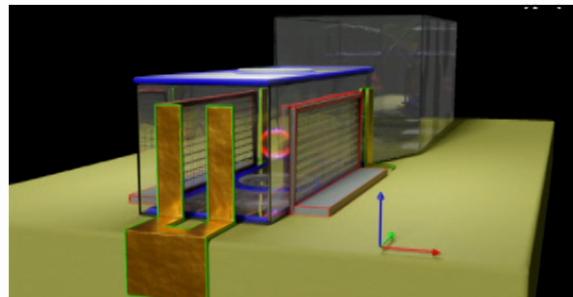
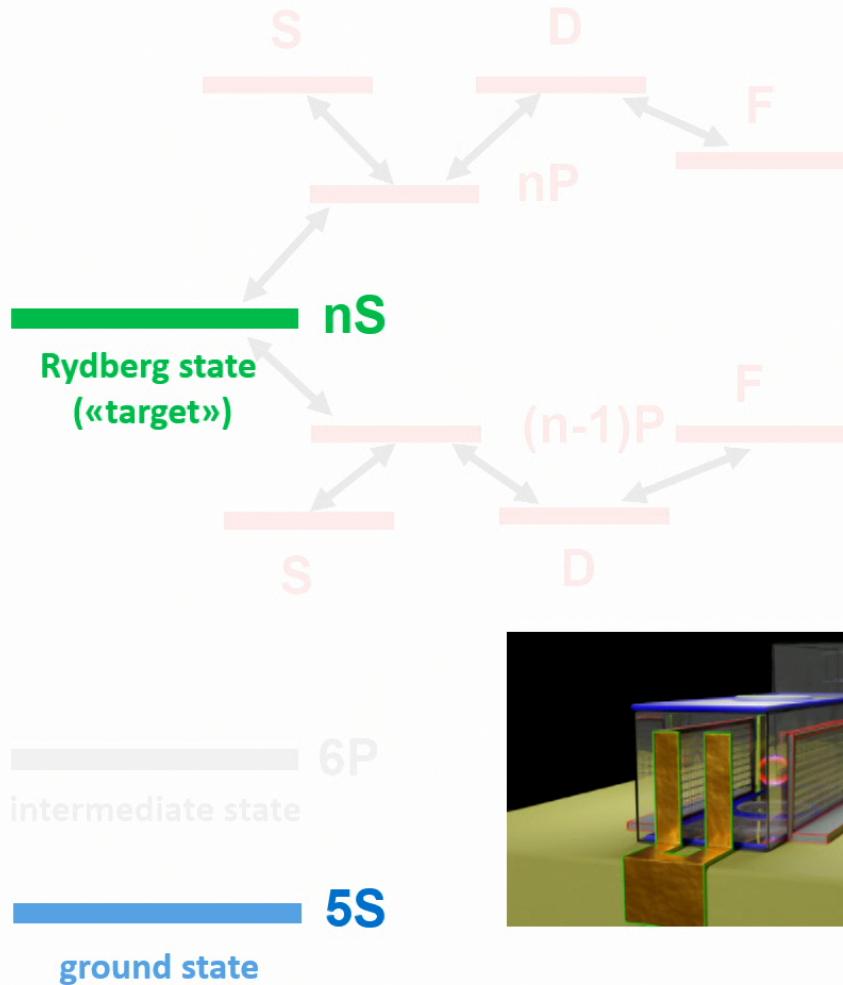
Now count the modes taking into account extra boundary conditions (electrodes)



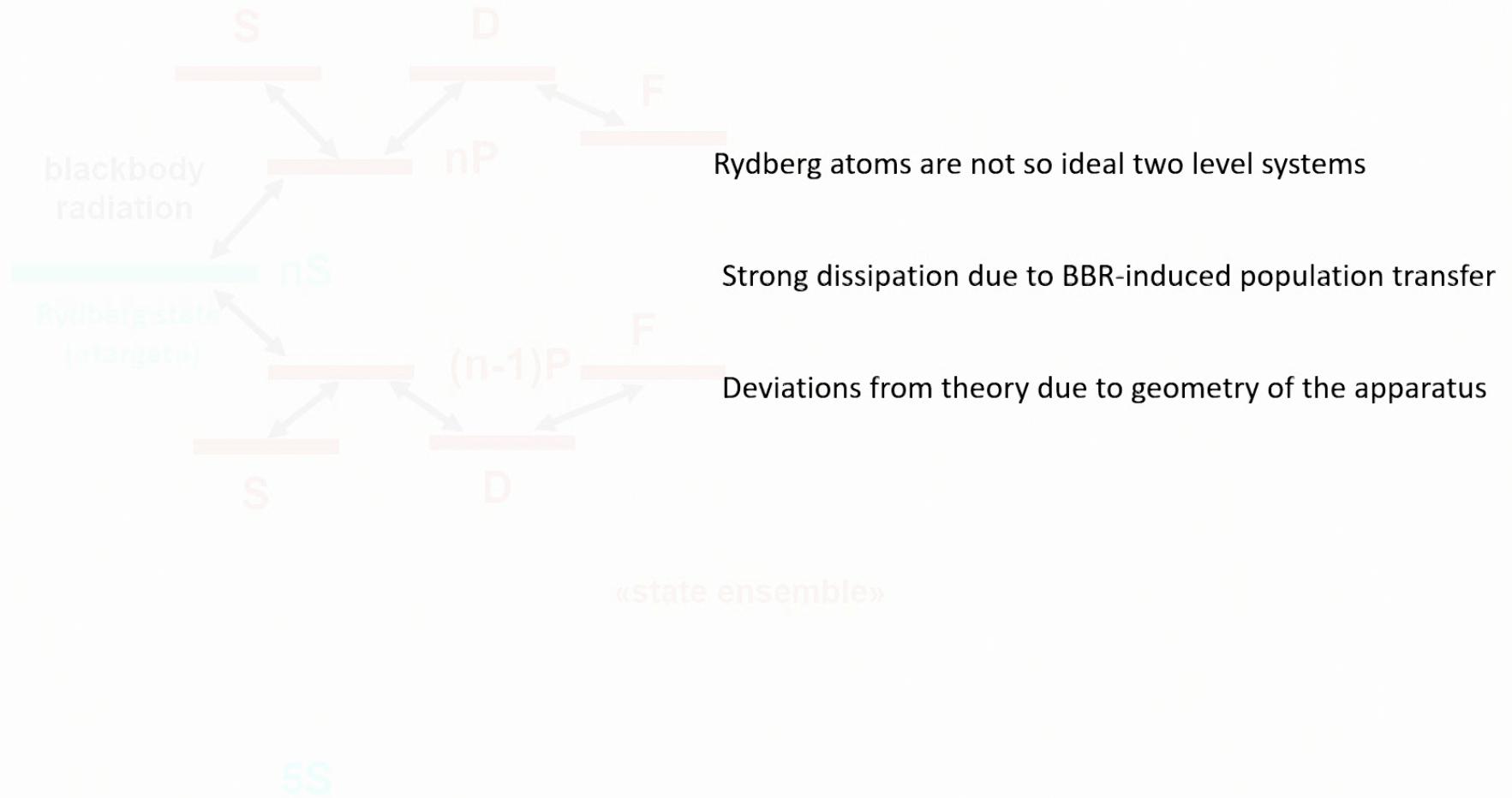
...or could it be the geometry...?



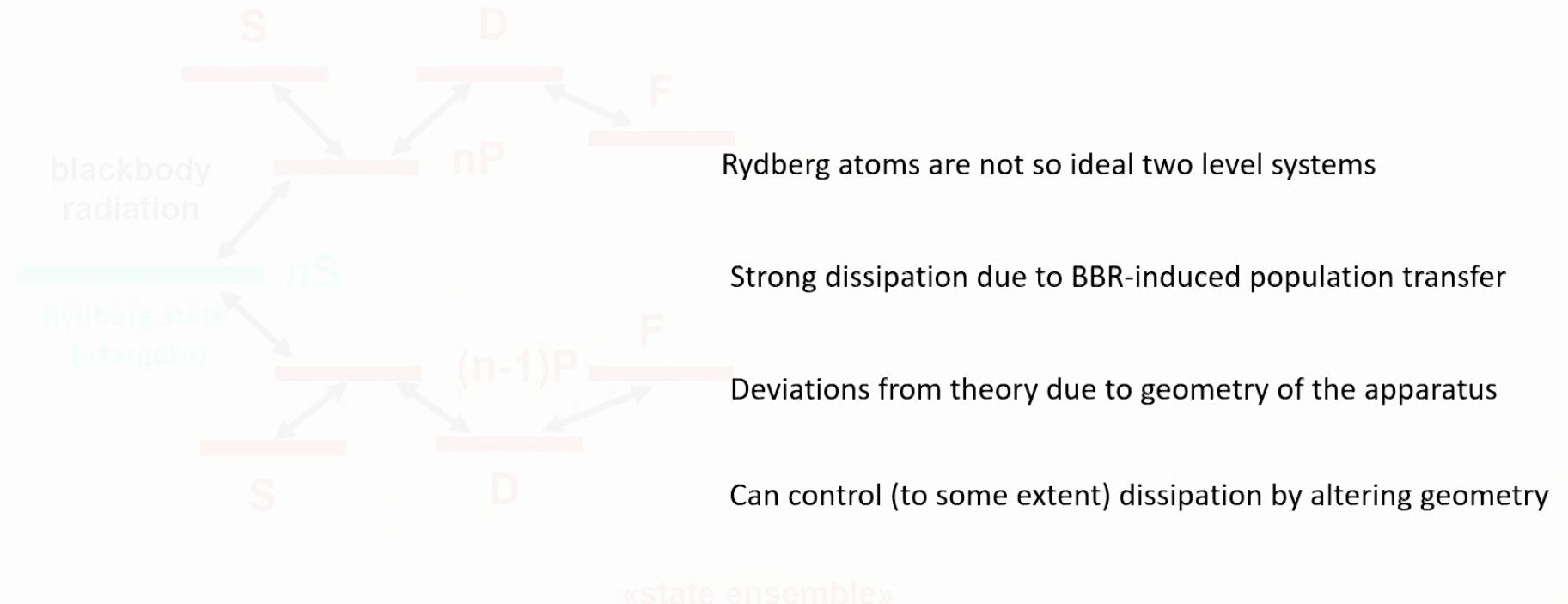
...or could it be the geometry...?



Summary: what we've learned



Summary: what we've learned



Thank you for your attention!

5S