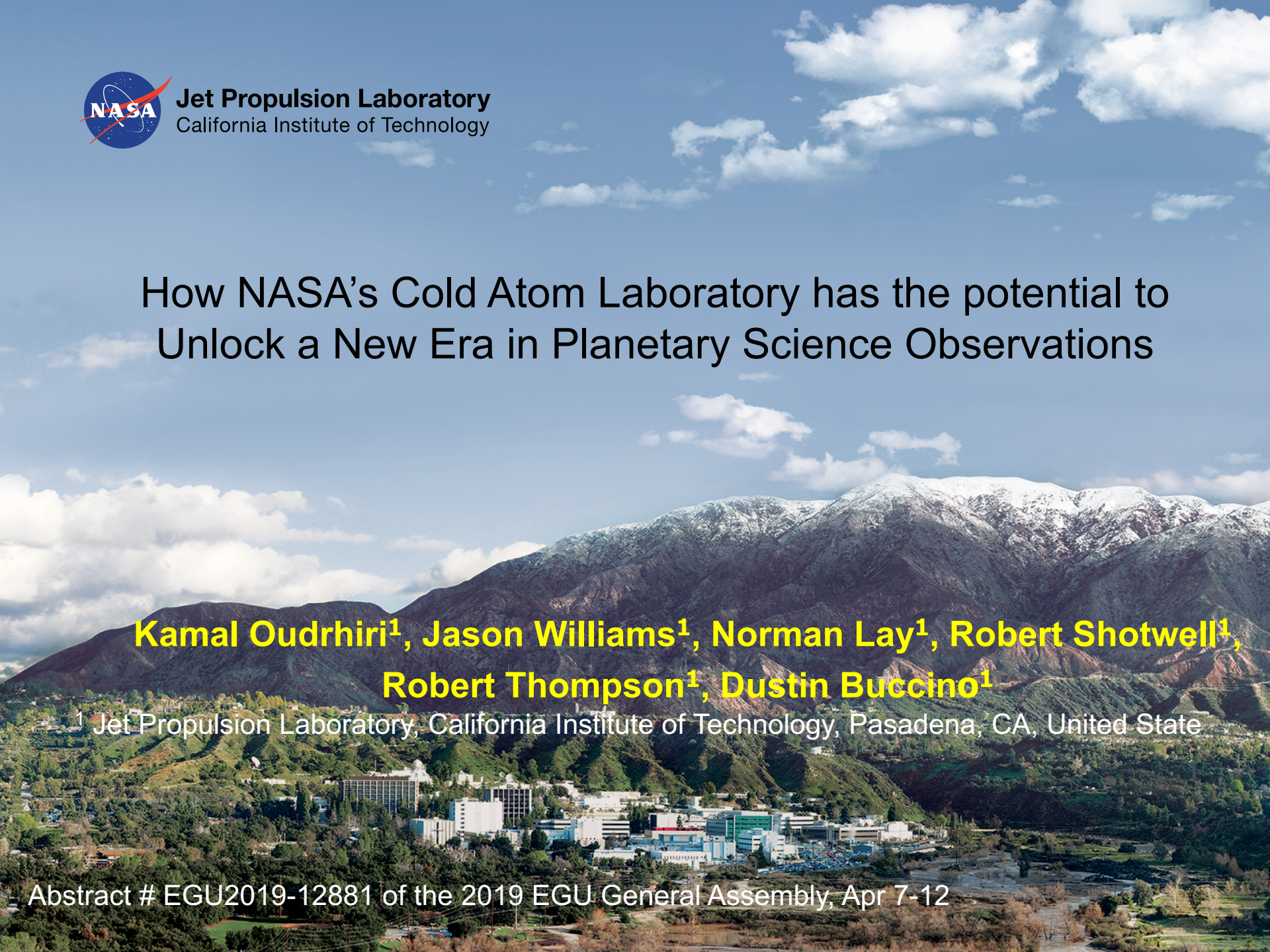


Jet Propulsion Laboratory
California Institute of Technology

# How NASA's Cold Atom Laboratory has the potential to Unlock a New Era in Planetary Science Observations

**Kamal Oudrhiri[1], Jason Williams[1], Norman Lay[1], Robert Shotwell[1], Robert Thompson[1], Dustin Buccino[1]**

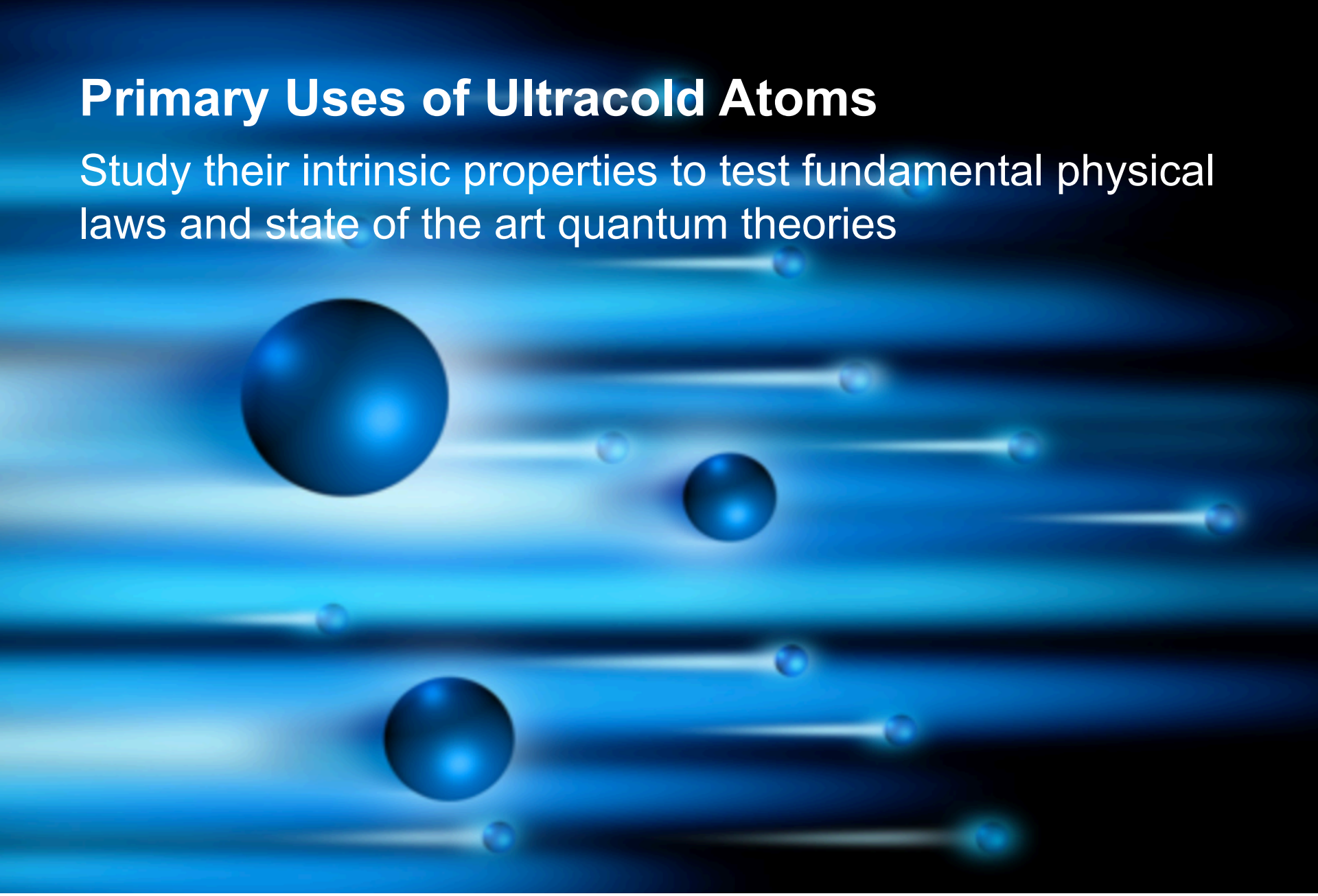
[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United State

Abstract # EGU2019-12881 of the 2019 EGU General Assembly, Apr 7-12

# Cold Atom Lab
# The Coolest Experiment in the Universe

# Primary Uses of Ultracold Atoms

Study their intrinsic properties to test fundamental physical laws and state of the art quantum theories



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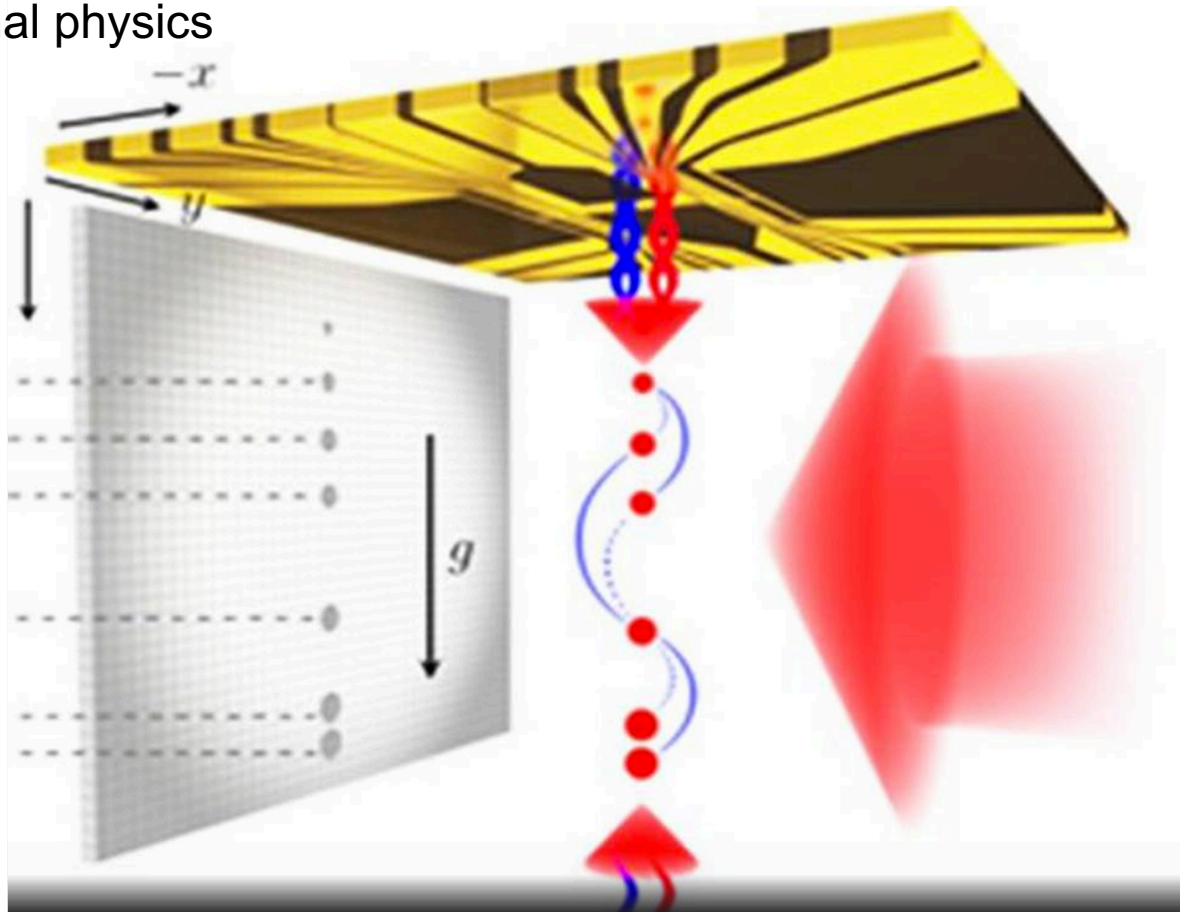
# Primary Uses of Ultracold Atoms

Exploit the sensitivity and quantum nature that comes with being ultracold to probe gravity and other inertial forces.

- Fundamental gravitational physics
- Gyroscopes
- Gravity gradiometers
- Accelerometers

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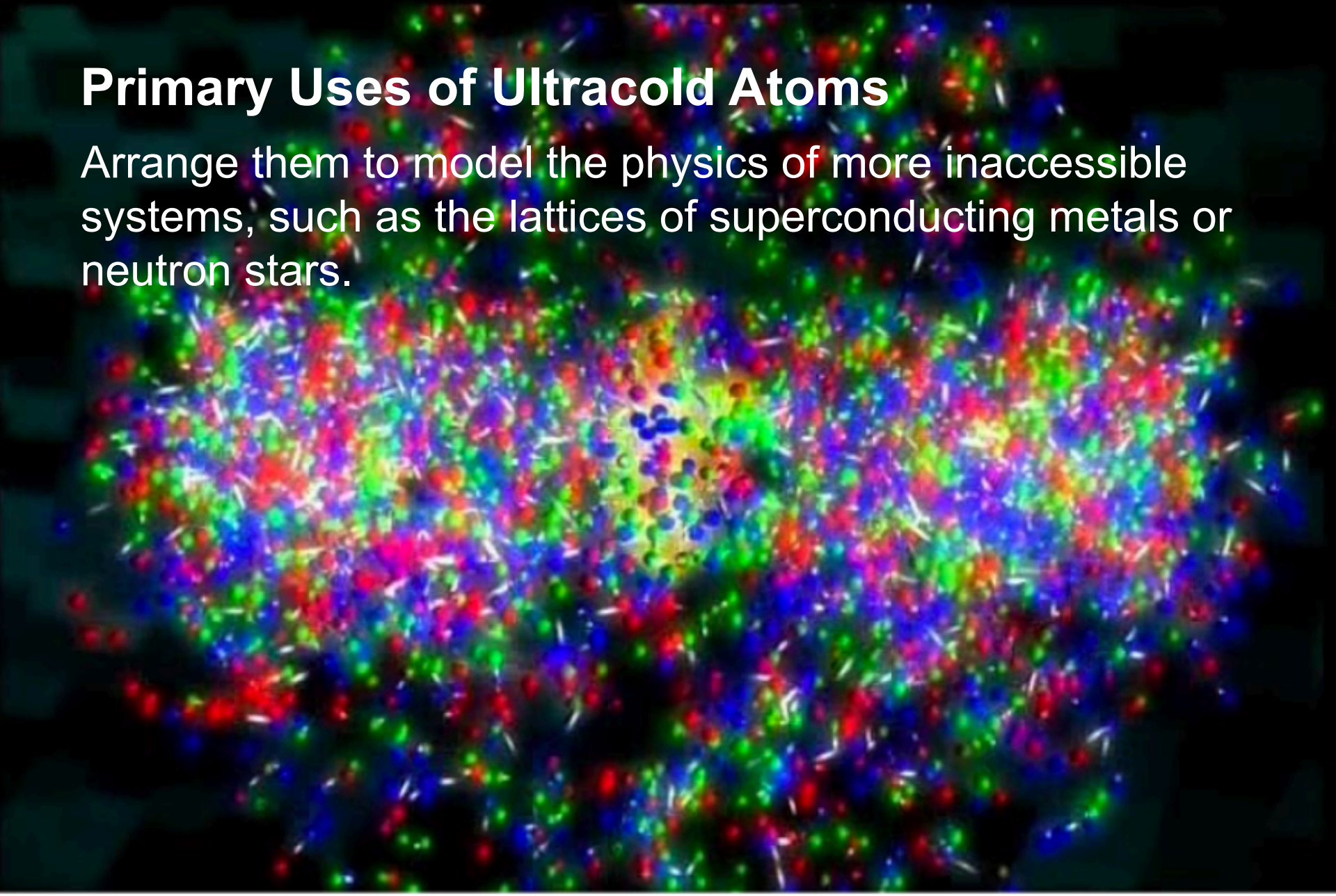
# Primary Uses of Ultracold Atoms

Arrange them to model the physics of more inaccessible systems, such as the lattices of superconducting metals or neutron stars.



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# Context: Ultracold Gases as an Enabling Technology

## The Ultracold Atom Race Continues…

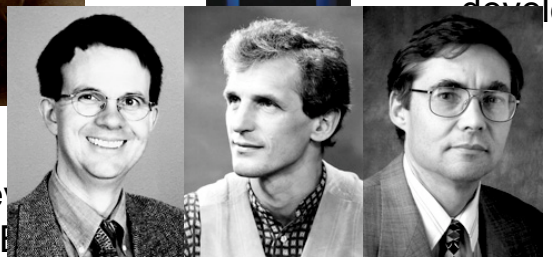
**1997** Nobel Prize in Physics
"for development of methods to cool and trap atoms with laser light"

**1892** Sir James Dewar liquefies hydrogen

Bill Phillips
JQI

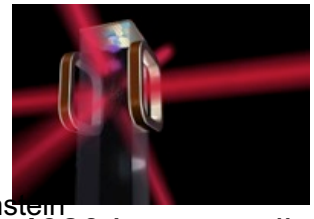
**1924** Bose
Einstein de
theory of B

**2001** Nobel Prize in Physics
"for the achievement of Bose-Einstein condensation in dilute gases"



Eric Cornell, JILA

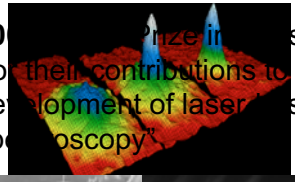
W. Ketterle MIT



**1980** Laser cooling developed

**2018** CAL BECs in orbit

**20** Prize in sics
"fo their contributions to the de lopment of laser sed precision sp oscopy"



**1**

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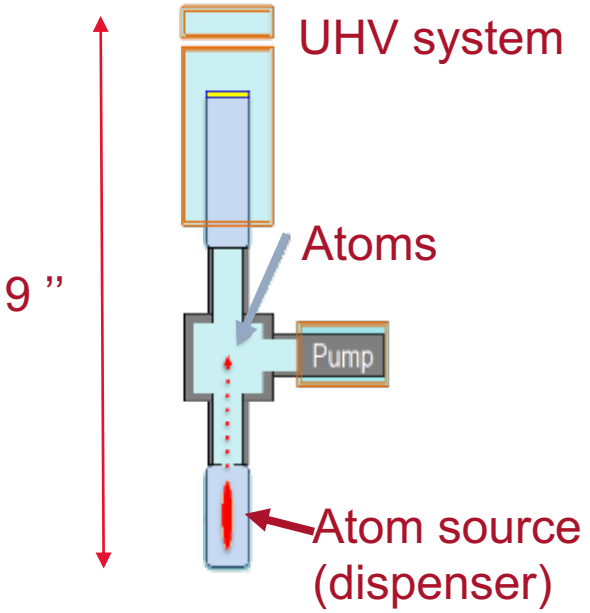
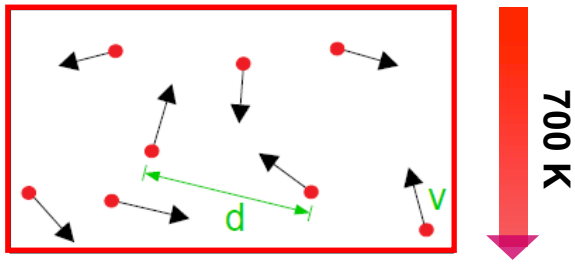
# The Road to Ultracold

Need Thermal Isolation:




Need Atoms:

Alkali metal dispenser (AMD)




**Activation of atomic source**
(Rubidium or Pottasium)

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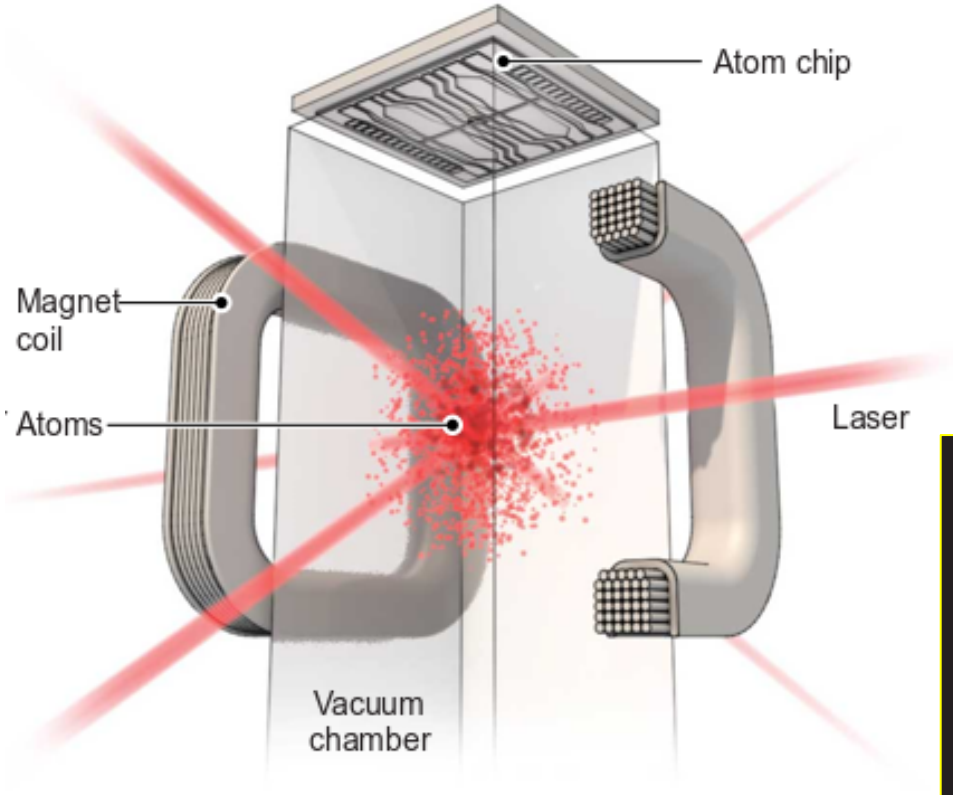


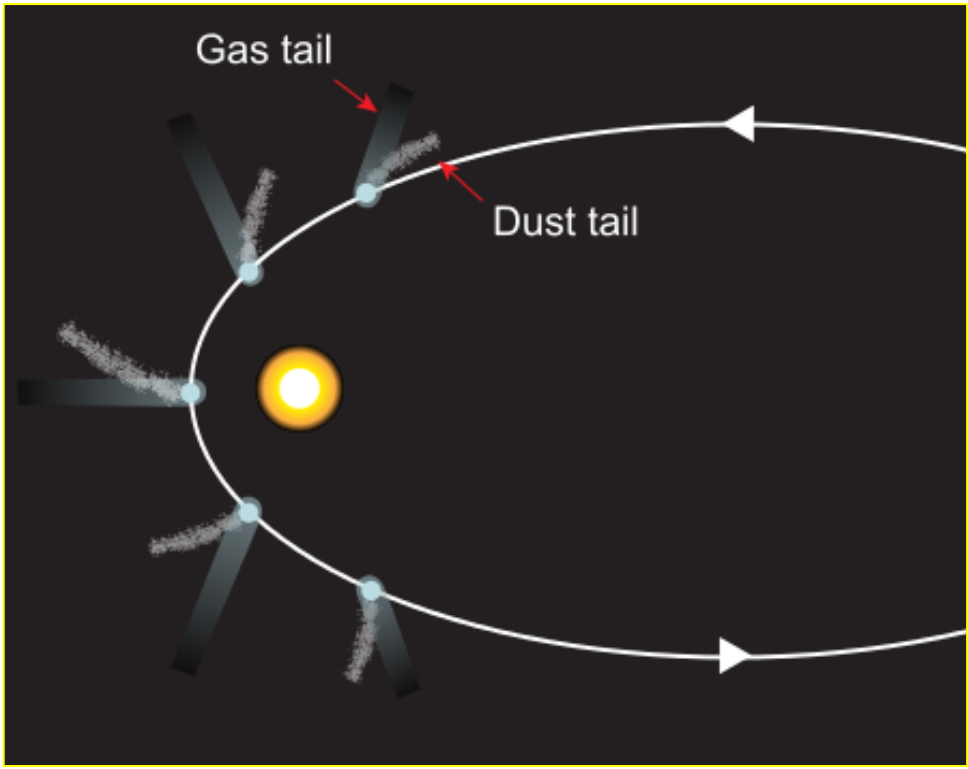


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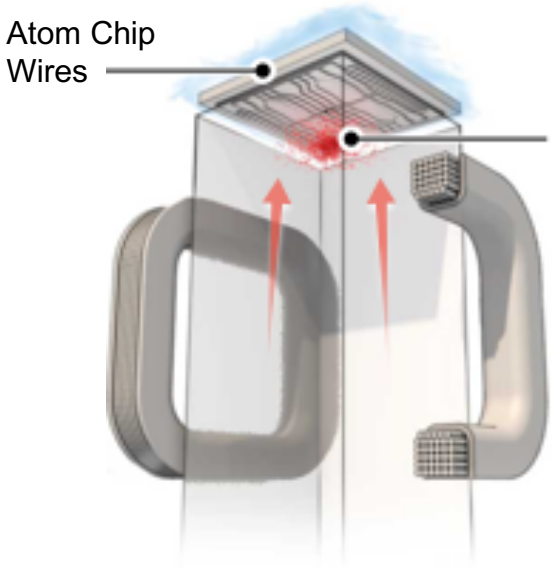
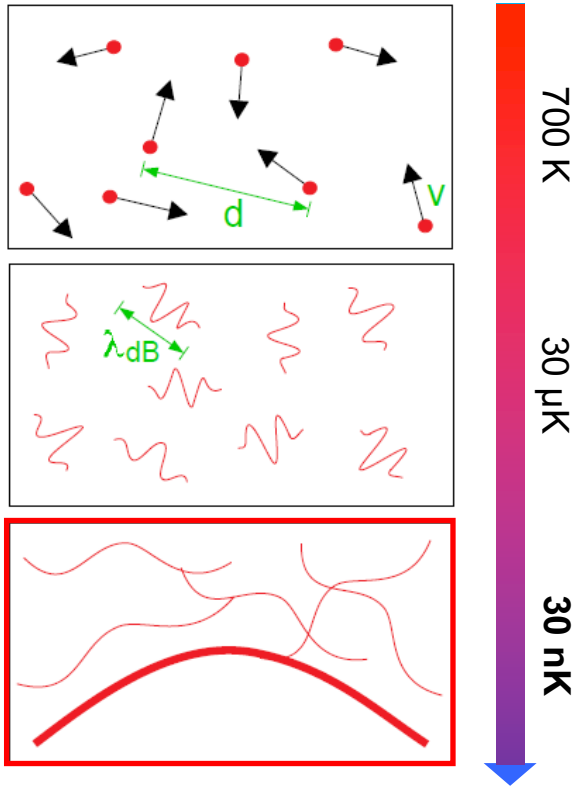
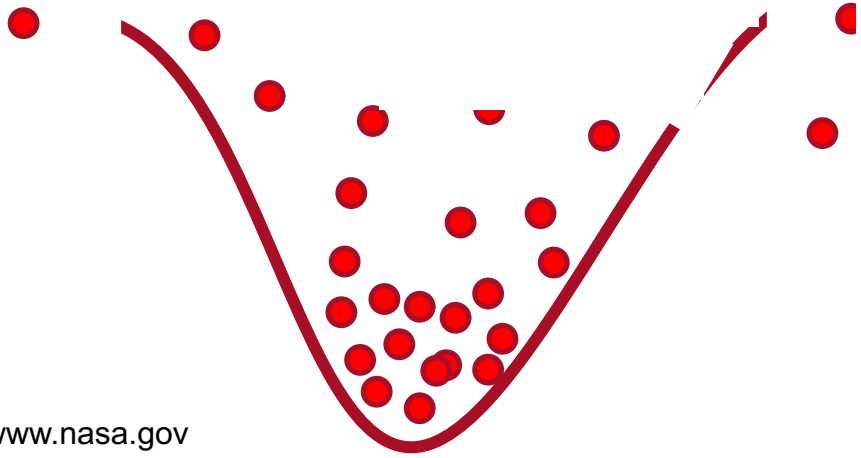



*Ketterle et al., Proc.of the Intl. Enrico Fermi school, 1999*



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$$\text{momentum} = \frac{h}{\text{wavelength}}$$

*lightweight*

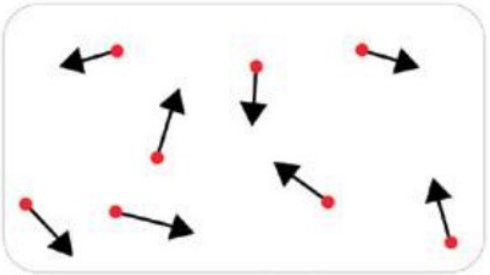
$$(\text{mass})(\text{velocity}) = \frac{h}{\text{wavelength}}$$

# What is a Bose-Einstein Condensate?

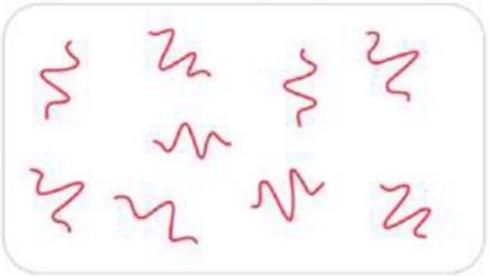
- All matter has both a wave and particle nature. As temperatures approach absolute zero, the size of the wave packets gets longer and longer. And then suddenly if we get them cold enough, they start overlapping and when they overlap, they start acting like particles, which have lost their identity. They all think they are everywhere at once.
- At high temperatures atoms behave as particles.
- If we cool atoms to extremely low temperatures, they undergo a very strange transformation. They undergo an identity crisis.
- Below this temperature, most of the atoms share the same wave function (for a gas of bosons)

Each one of these atoms starts to display wave-like properties.

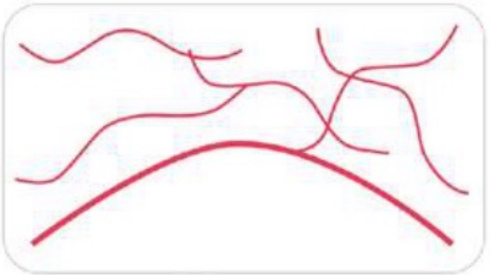
**High Temperature:**
**"Billiard balls"**



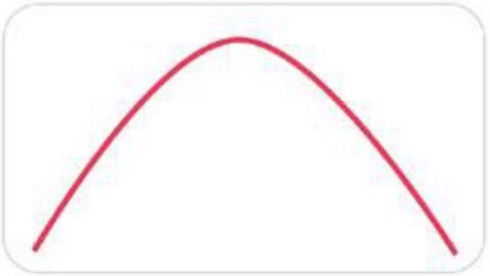
**Low Temperature:**
**"Wave packets"**
**T~1 microKelvin**



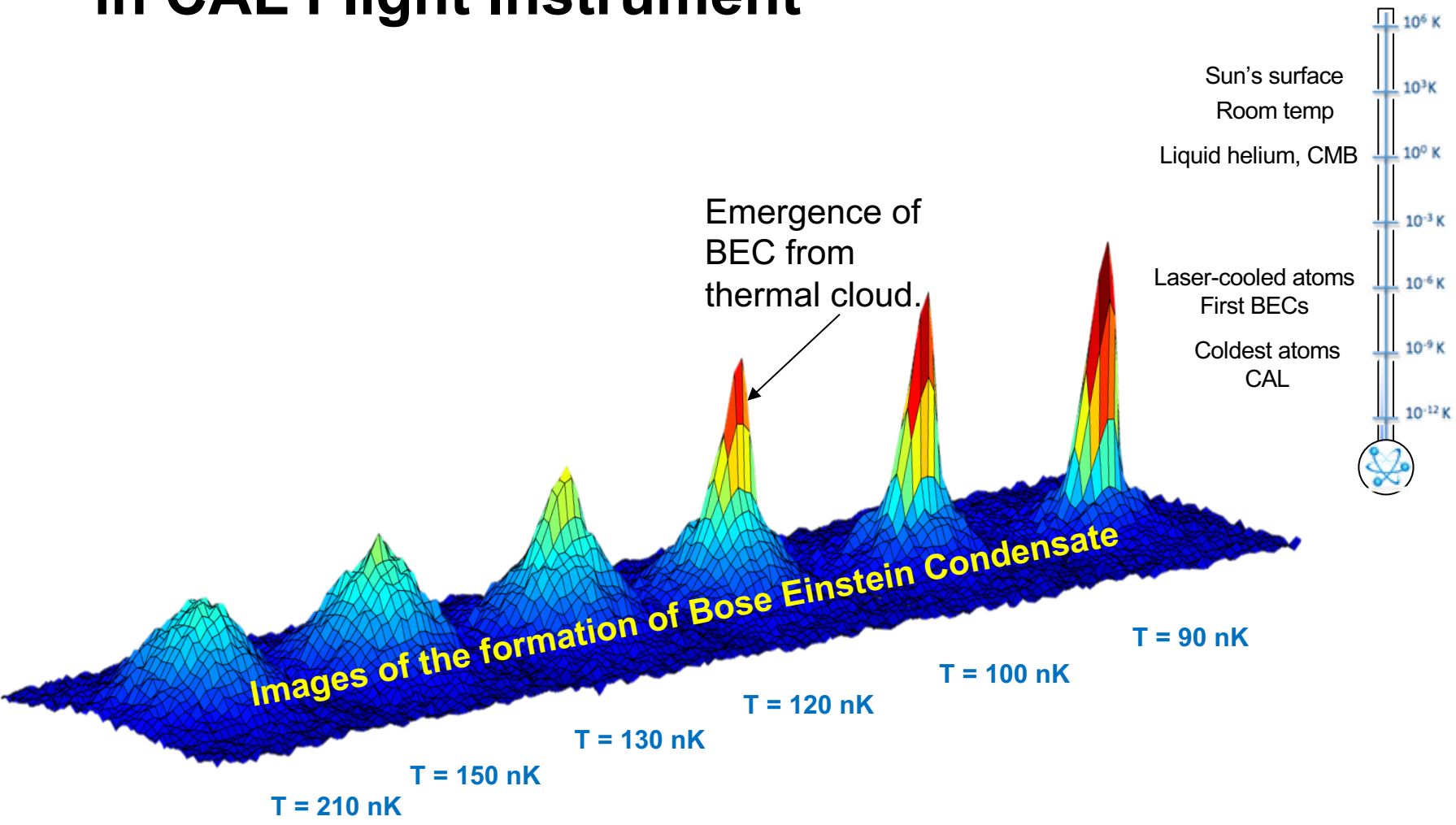
**Bose-Einstein Condensation**
**"Matter wave overlap"**
**T~10 nanoKelvin**



**Pure bose Condensate**
**"Giant matter wave"**
**T~1 picoKelvin**



# First Observation of Bose-Einstein Condensate in CAL Flight Instrument

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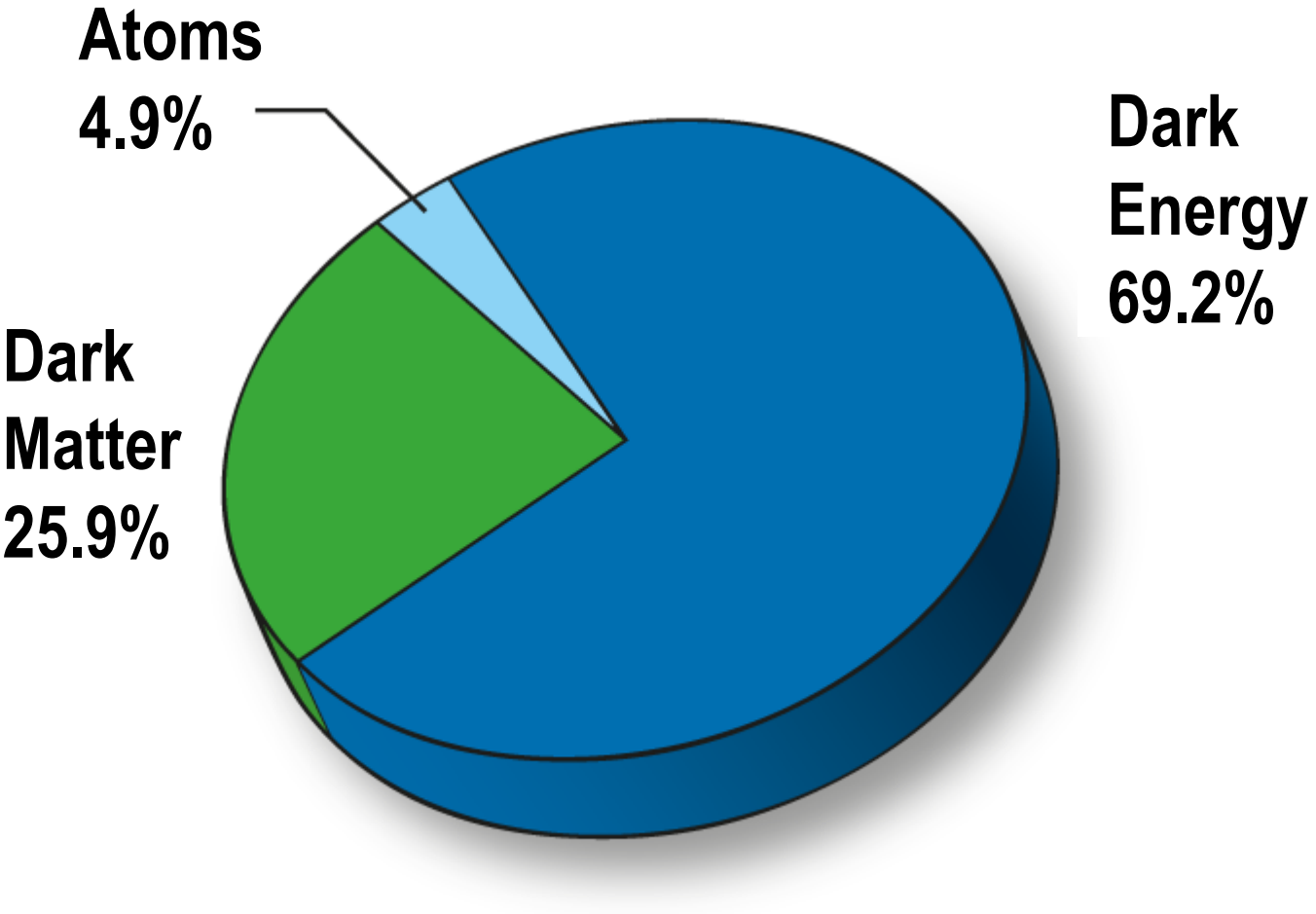
# Content of the Universe

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Data Credit: Plank Mission





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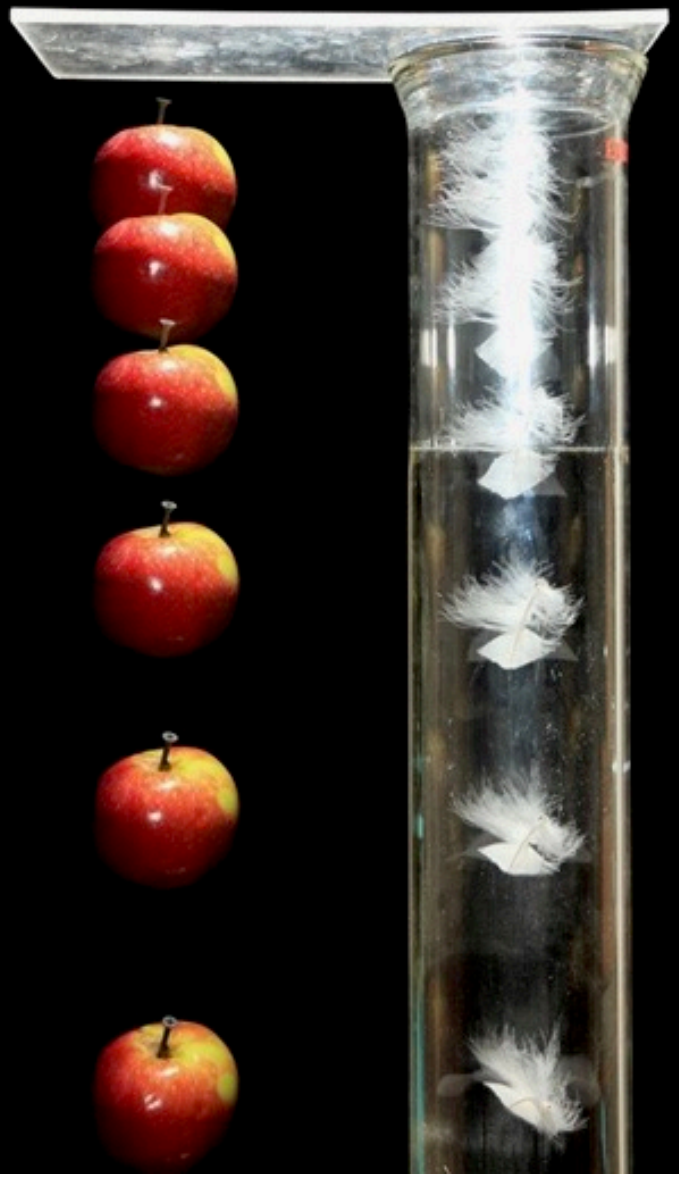
# CAL Science: Testing Einstein

Will a potassium atom and a rubidium atom fall at precisely the same rate?



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# CAL Science: The Quest for Colder Temperatures

This research focuses on methods of  expansion into exceptionally weak traps to achieve extremely low temperature; and on utilizing these samples for atom interferometry

Adiabatic cooling: let gas expand into very weak trap.  As it expands it steadily cools…

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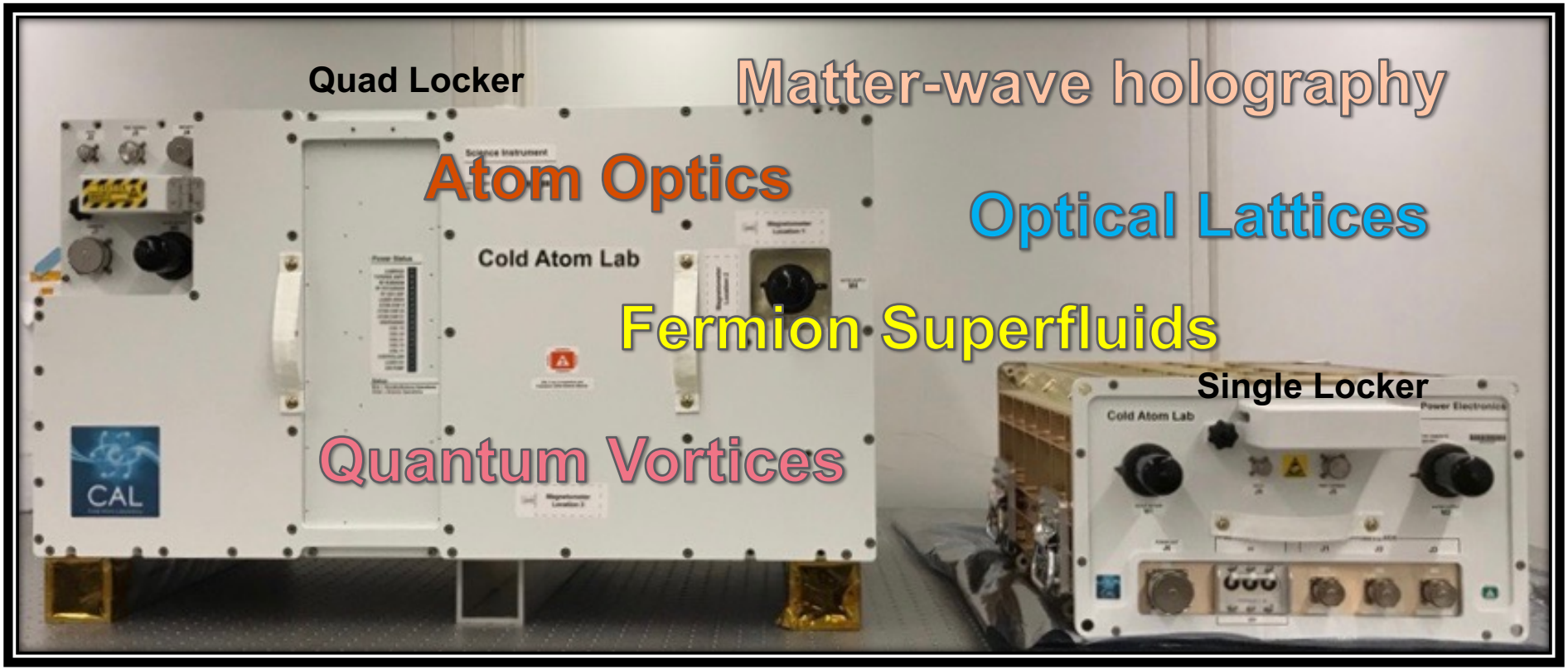
# The CAL Facility: A Cutting Edge Ultracold Atom Laboratory in Space

## CAL represents limitless potential for future investigations!

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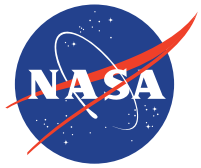
# THANK YOU!

## Acknowledgement

**Copyright 2019. This work was carried out at the Jet Propulsion Lab, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Government sponsorship acknowledged.**

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