

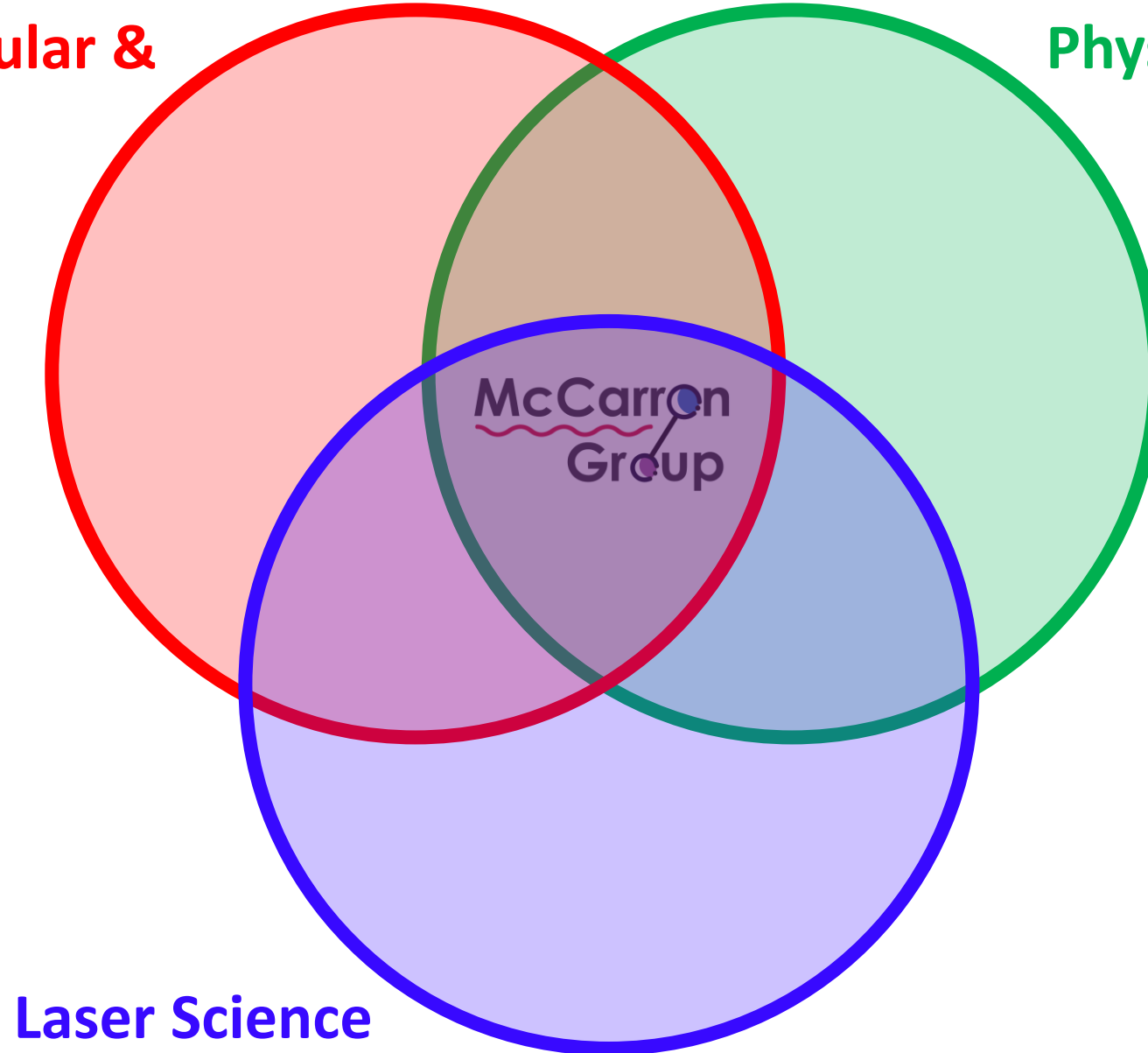
# Laser-Cooled Molecules for Quantum Science & Controlled Organic Chemistry



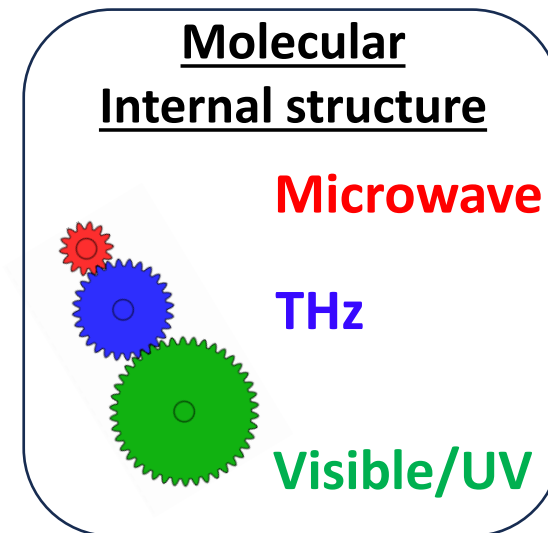
# Research Group

**Atomic, Molecular &  
Optical Physics**

**Physical Chemistry**



**Laser Science**

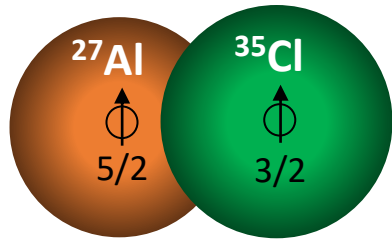


# Expertise & Core Strengths:

## Quantum science w/ polar molecules

Long range (1  $\mu\text{m}$ )

Long times (10 s)



$$|\psi\rangle = |n, v, J, F, m_F\rangle$$



**Goal:**

$10^6$  molecules

10  $\mu\text{K}$

PSD  $\sim 1$

$$V_{\text{int}}(\mathbf{r}) = \frac{d^2}{4\pi\epsilon_0} \frac{(1 - 3\cos^2\theta)}{|\mathbf{r}|^3} + \frac{4\pi\hbar^2 a}{m} \delta(\mathbf{r})$$

Figure of merit:

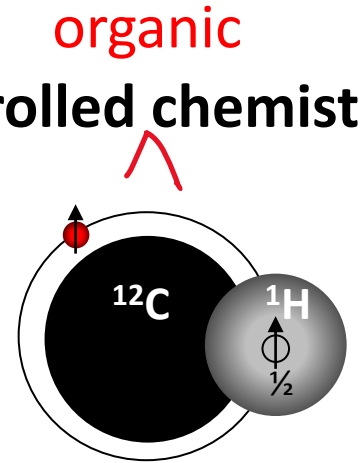
$$\frac{E_{dd}\tau_c}{h}$$



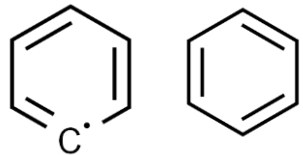
## Quantum state-controlled chemistry

Short-range (10 nm)

Short-times (1  $\mu\text{s}$ )

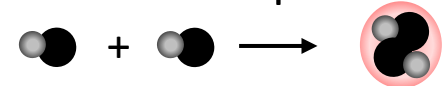


**Cold** ( $\leq 20$  K) – reaction rates relevant to ISM

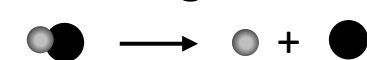


**Ultracold** ( $< 1$  mK) – quantum-state control

→ collision complexes?



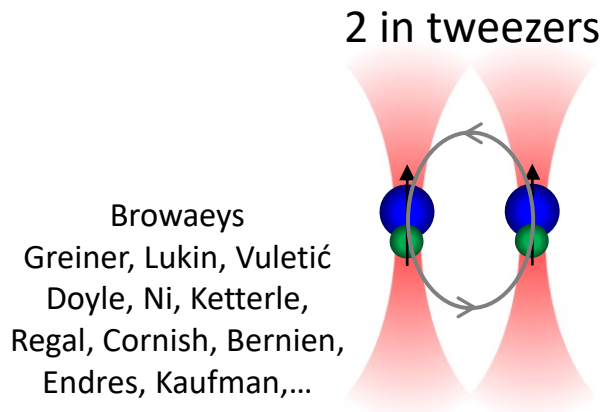
→ scattering resonances?



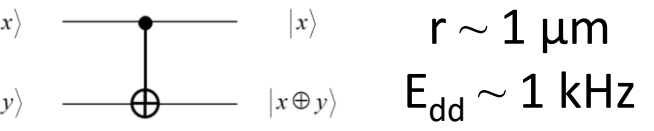
# Exciting Opportunities

$$V_{\text{int}}(\mathbf{r}) = \frac{d^2}{4\pi\epsilon_0} \frac{(1 - 3\cos^2\theta)}{|\mathbf{r}|^3} + \frac{4\pi\hbar^2 a}{m} \delta(\mathbf{r})$$

## Quantum Computation



### Tweezer arrays



### “Bottom-up approach”

(‘program’ each molecule)



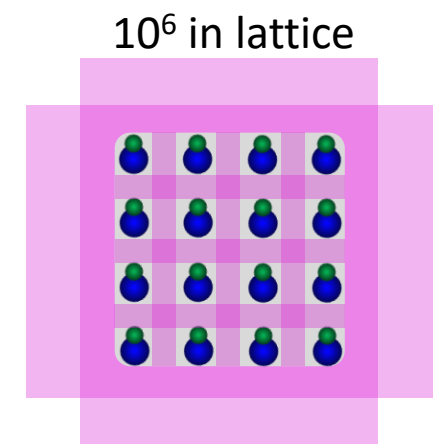
## Quantum science w/ polar molecules



$$\hat{H}$$

simplified model

## Quantum Simulation



### Short-wavelength lattice

$r \sim 100 \text{ nm}$   
 $E_{\text{dd}} \sim 10\text{-}100 \text{ kHz}$

### “Top-down approach”

(engineered interactions)



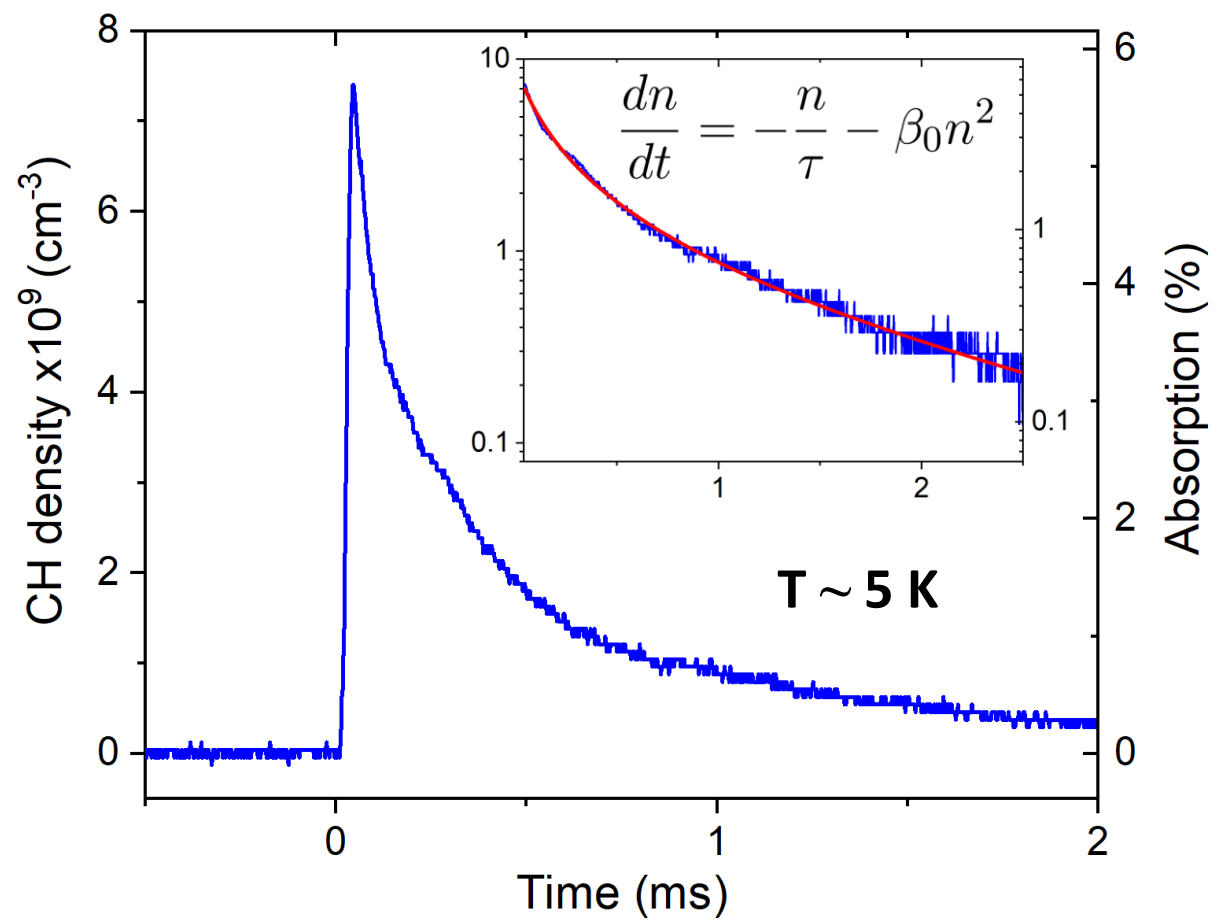
We can control *everything*... potential, interactions, quantum statistics etc.

# Exciting Opportunities

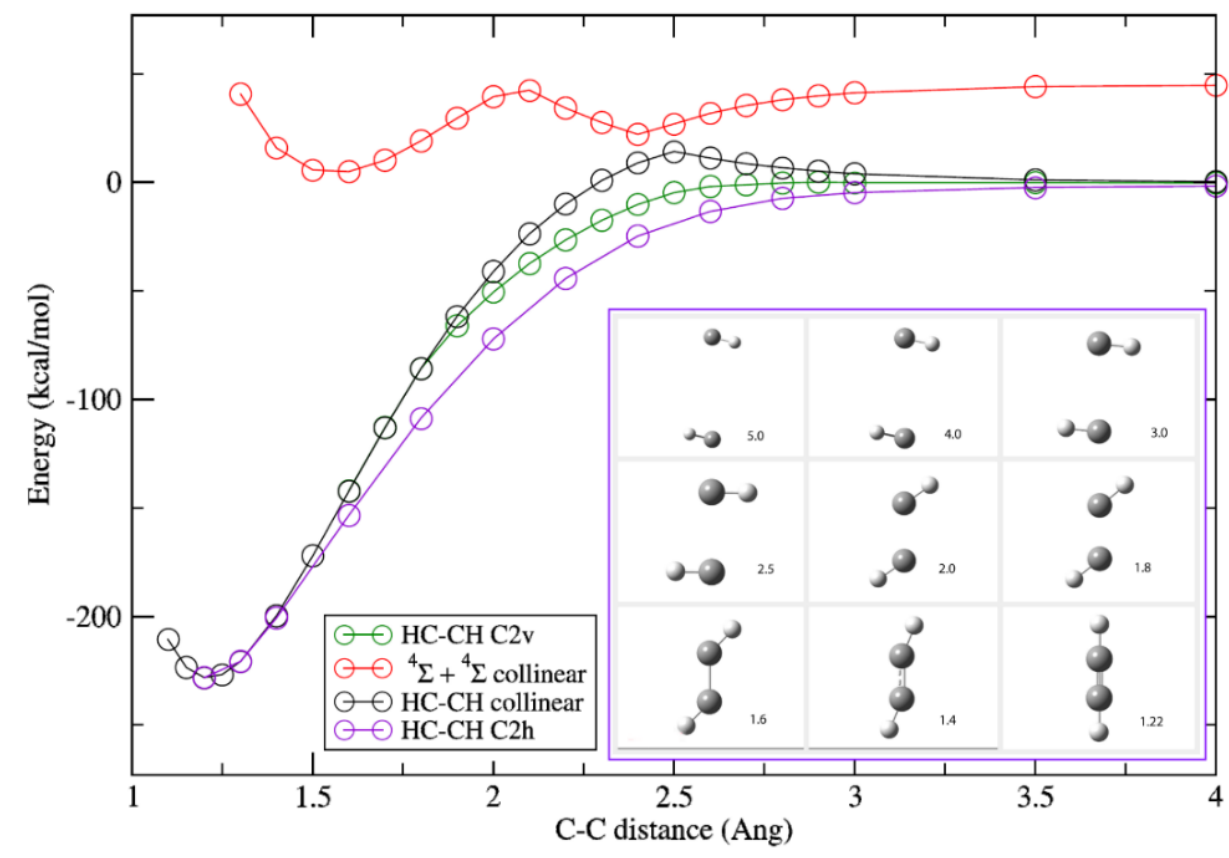


## organic Quantum state-controlled chemistry

Already detect cold organic chemistry...



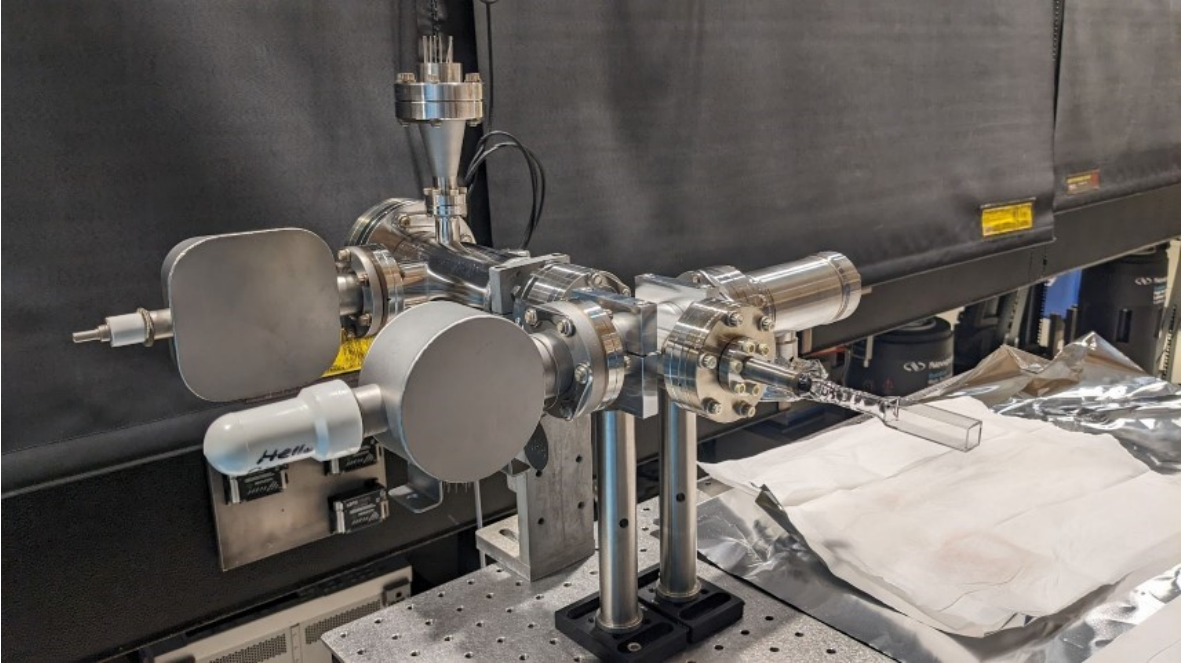
Future: Map out potential energy surface





# Exciting Opportunities

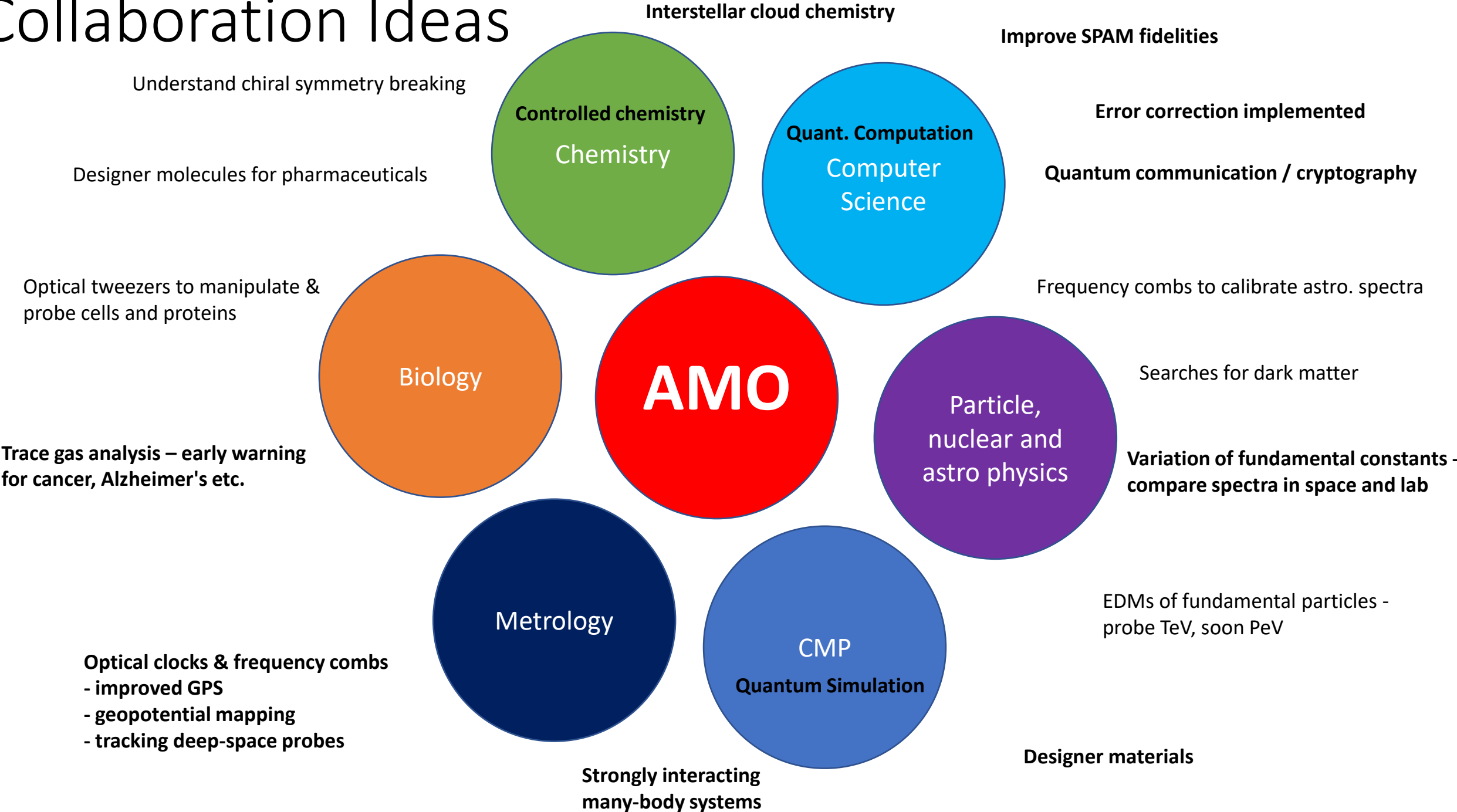
## “Quantum Matters” – Exposing local high school students to QM



**UConn**  
UNIVERSITY OF CONNECTICUT



# Collaboration Ideas





# Acknowledgements

## Graduate Students



Mark  
Semco



William  
Wortley

## Undergraduate Students



Spencer  
Macri



Joseph Van  
Vlack



Jefferson  
Wang



@mccarrongroup

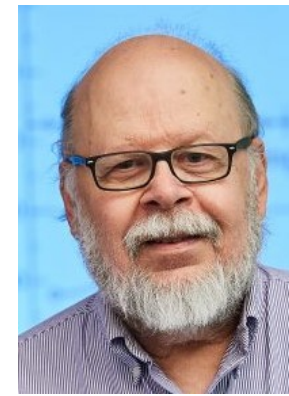


themccarrongroup.com

## Collaborators



Börge  
Hemmerling



John  
Montgomery



Boris  
Sartakov



## DURIP

## Former Grad. Students

Jamie Shaw – MIT LL  
Joseph Schnaubelt - UConn

