**Polar Molecules in electronic vibrational ground state**

- **Towards Ultra-Cold Ground-state Polar Molecules in the Lab**
  - Experiment: (ii) closed annular loop; Delboeuf, Draves, Appleton, Weidemüller, Brillouin.
  - Techniques not being developed for:
    - Cooling & trapping (cooler cold field CO2)
    - Preparation via :
      - Photodissociation (LIF, INS, IR, ...)
      - E.g. 2-modules RECl in M=Phase
    - Rotor gas cooling, laser desorption, (CO2, laser, IR, ...)
  - AND Gasoline: Optical tracking, Optical Lattice, Measurements, ...

**Lattice Spin Models I: Spin-1/2**

- AM, G. K. Brennen, P. Zoller.
- Simplified model in CMB: dense washout complex systems
- Two spin range order via exchange interaction
- Direct contact in cooling spin-operators with similar phases
- Symmetry preserving directed exchanges; related to symmetric properties under the confinement interaction
- Derived properties of the model:
  - Spin operators are highly symmetric in spin and space coordinates.
  - Invariant of the model structure under exchange
- Challenges: Full potential strongly relies on these models
- Can be built and their properties can be predicted

**Physical Ingredients**

- Reduction with molecular quantum states
- Optical lattice (see: spin-1/2 model)
- Conduction electrons, light-polarized plasmonic states
- Spin-1/2 – intermediate range of interatomic molecular potentials
- Antiferromagnetic interactions from spin projections: +1 \( \rightarrow -1 \) +/ –
- Strong spin-orbit rotational symmetry: +/ –

**Lattice Spin Models II: Spin-1**

- G. K. Brennen, AM, P. Zoller.
- Extension of model from Spin-1/2 to integer spin models
  - e.g. Realization of 2D generalized halide Molecule

**Spin-Patterns via Microwave-fields**

- BO-parametric for two molecules with hyperfine structure interaction via dipole-dipole interaction
  - B: \( B = B_0 + B_0 R \) \( \propto \gamma_2 \)
  - Ground-state: weak Van der Waals 1
  - Excited-state: strong dipole 2
- Interaction via spin resonance

**1D Generalized Halide Model**

- Realization of 1D Generalized Halide Model: \( \text{H}_2^+ \), \( \text{D}_2^+, \text{C}_2^+ \)
  - Molecular Properties: Electronically, vibrationally, Raman, IR, VIB
  - Optimization of 4 RH fields \( \text{H}_2^+, \text{D}_2^+, \text{C}_2^+ \)
  - Interactions on nearest neighbor link

**Verification**

- Spin structure factor

**Quantum Phase Transition**

- Effective 2D interaction by integrating out transverse motion

**Tailoring potentials with DC and AC fields**

**Design of inter-particle interactions**

- 1-particle: single molecule
  - Optical 2D mapping
  - Rigid rotor in DC: electric field induces permanent dipole moment in rotational ground state
  - \( \text{Halide:} \text{Neurotronic, Enervational, VIB} \)
  - Orbital interaction with \( \text{D}_2^+ \) in rotating field

**Stability via transverse confinement**

- Effective interaction (DC case):
  - \( V_C = V_C \left( \frac{\mathbf{p}_1 \cdot \mathbf{p}_2}{\mathbf{r}_1 \cdot \mathbf{r}_2} \right) \)

**Spin-rotation coupling**

- Gauge coupling of spin-rotation with coordinate space
  - \( R \left( \theta \right) \left( \mathcal{R}_\theta \right) \)
  - Rigid rotor in AC: angular momentum
  - U(1) x SO(3) x SO(3)

**Rigidity of the 1D chain**

- Effective 1D interaction: by integrating out transverse motion

**2D-disking of spin region**

- Potential engineering with several e.g.
  - Effective 2D interaction: by integrating out transverse motion
  - \( R \left( \theta \right) \left( \mathcal{R}_\theta \right) \)
  - Rigid rotor in AC: angular momentum