

discuss the physical origin of the metastability of the spinor BEC system.

E01 96 Entangled state preparation enhanced by reinforcement learning JUN-JIE CHEN,* YOU LI,[†] *Tsinghua Univ* Fast and accurate generation of useful quantum states is fundamental to quantum information and quantum precision measurement physics. In actual applications, well-designed experimental protocols are called for. The recently developed learning frame of reinforcement learning (RL) can maximize a given reward by automatically exploring and exploiting without the necessity of any prior knowledge. This work reports our discovery of an efficient, effective, and high fidelity protocol with RL, that is capable of producing a target Twin-Fock state by driving external field from an initial polar state of a ferromagnetic spin-1 atomic Bose-Einstein condensate. For a small system of two atoms, we show that protocol from RL corresponds to the optimized one reaching the quantum speed limit. When illustrated in phase space, it clearly shows that the protocol from RL corresponds almost to a geodesic path connecting the initial and the target state. When applied to a many body system, we find that RL generally can offer a better solution than the old wisdoms such as adiabatic passage *etc.* can provide for. Furthermore, we find the RL protocol is robust to various types of noises in real experiments.

*State Key Laboratory of Low Dimensional Quantum Physics, Department of Physics, Tsinghua University, Beijing 100084, China.

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E01 97 Cavity-mediated tunable spin mixing in spinor atomic Bose-Einstein condensates MING XUE,* JUN-JIE CHEN,[†] *Tsinghua Univ* ZHI-FANG XU,[‡] *SUSTech* LI YOU,[§] *Tsinghua Univ* Spin mixing usually refers to the dynamics originating from binary spin exchange collisions in a spinor atomic Bose-Einstein condensate. This work presents a practical scheme for realizing spin mixing with tunable interaction strength and effective quadratic Zeeman shift by placing the condensate in an optical cavity, whereby two atomic Raman transitions are accomplished via a cavity photon and two laser beams, leading to the generation of an effective spin-exchange interaction. The effective Hamiltonian are derived by using Floquet-Magnus expansion. For increased strength, the frequencies of the two σ -polarized lasers are chosen to compensate the spin-exchange energy mismatching. With atoms far off-resonant due to a large bias magnetic field and the cavity photonic mode only virtually excited, our scheme is found to be robust against cavity dissipation and magnetic field noise.

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[†]State Key Laboratory of Low Dimensional Quantum Physics, Department of Physics, Tsinghua University, Beijing 100084, China.

[‡]Shenzhen Institute for Quantum Science and Engineering and Department of Physics, Southern University of Science and Technology, Shenzhen 518055, China.

[§]State Key Laboratory of Low Dimensional Quantum Physics, Department of Physics, Tsinghua University. Collaborative Innovation Center of Quantum Matter, Beijing 100084, China.

E01 98 Spin-incoherent Luttinger liquid of one-dimensional $SU(\kappa)$ fermions HSIANG-HUA JEN, *Institute of Physics, Academia Sinica* SUNGKIT YIP, *Institute of Physics and Institute of Atomic and Molecular Sciences, Academia Sinica* We inves-

tigate spin-incoherent one-dimensional (1D) $SU(\kappa)$ fermions in a harmonic trap. Specifically we focus on Tonks-Girardeau gas limit where its density is sufficiently low that effective repulsions between atoms become infinite. In such case, spin exchange energy of 1D $SU(\kappa)$ fermions vanishes and all spin configurations are degenerate, which automatically puts them into spin-incoherent regime. In this limit, we can write down the spatial wave functions by the conventional Slater determinant, and furthermore we are able to express the single-particle density matrices in terms of those of anyons. This allows us to numerically simulate the number of particles up to $N = 32$. We numerically calculate single-particle density matrices for (1) equal populations for each components (balanced) and (2) all S_z manifolds included. We find their momentum distributions are broadened due to highly degenerate spin configurations, a signature of spin-incoherent regime. We then compare numerically calculated high momentum tails of momentum distributions with analytical predictions which are proportional to $1/p^4$, in good agreement. Thus, our theoretical study provides a direct comparison with experiments of repulsive multicomponent alkaline earth fermions.

E01 99 Spin-Interaction Effects for Ultralong-range Rydberg Molecules in a Magnetic Field CHRISTIAN FEY, FREDERIC HUMMEL, *Center for Optical Quantum Technologies, University of Hamburg, Germany* PETER SCHMELCHER, *Center for Optical Quantum Technologies, The Hamburg Centre for Ultrafast Imaging, University of Hamburg, Germany* Ultralong-range Rydberg molecules (ULRM) are "giant molecules" consisting of a Rydberg atom and one or more polarizable ground state atoms [1,2]. The Born-Oppenheimer potential surfaces of these molecules mimic the oscillatory structure of the Rydberg wave function and are therefore extremely sensitive to weak external fields. This property can be exploited to control the molecular geometry, e.g. to orient the molecular axis relative to a given magnetic field axis [3,4]. On our poster we will focus on the role of different spin couplings for the formation of Rb d -state ULRM in magnetic fields, e.g. the relative configuration of the Rydberg spin and the electronic spins of the ground state atoms (singlet vs. triplet) or the hyperfine configurations. We'll see that the magnetic field offers possibilities to create a large variety of molecular states in different spin configurations as well as in different spatial arrangements [5].

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⁴Krupp, Gaj, Balewski, Ilzhöfer, Hofferberth, Löw, Pfau, Kurz, and Schmelcher, PRL **112**, 143008 (2014).

⁵Hummel, Fey, and Schmelcher, arxiv 1711.08748.

E01 100 Dual Species Rydberg and Collisional Interactions in an Optical Dipole Trap* MATTHEW EBERT, GARRETT HICKMAN, ALPHONSE MARRA, XIAOYU JIANG, TRENT GRAHAM, MARK SAFFMAN, *University of Wisconsin-Madison* UNIVERSITY OF WISCONSIN-MADISON TEAM We present progress in demonstrating Rydberg interactions between a single Rb and a single Cs atom simultaneously trapped in a single 976 nm optical tweezer. Rydberg levels in heteronuclear systems have different quantum defects, as opposed to homonuclear systems, and can therefore be chosen to minimize the Forster defect and increase the Rydberg interaction strength beyond symmetric Rydberg pairs at comparable energy levels. Additionally, multi-species systems are distinguishable and can be frequency multiplexed in a straightforward manner. Frequency multiplexing both the state preparation and

state readout is used in characterizing elastic and inelastic collision rates between Rb and Cs, as well as enabling crosstalk free ancilla measurements for quantum error correction.

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E01 101 Using phase space methods to study many-body localization in spin systems with long-range interactions* SEAN MULEADY, *Department of Physics, University of Colorado, Boulder* ARGHAVAN SAFAVI-NAINI, MICHAEL L. WALL, JILA, NIST, and *University of Colorado, Boulder* RAHUL NANDKISHORE, *Department of Physics, University of Colorado, Boulder* ANA MARIA REY, JILA, NIST, and *University of Colorado, Boulder* Many-body localized (MBL) systems fail to thermalize and may be used as robust quantum memories with intriguing entanglement properties. In one-dimensional systems with short-range interactions, we have been able to gain an excellent understanding of the nature of the MBL phase. However, very little is known about the fate of the MBL phase when the interactions are extended to long range. Here, we use extensive numerical simulations to study the existence and characteristics of an MBL phase in the presence of power-law decaying interactions. We use matrix product state (MPS) methods, which are exact but limited to modest system sizes, as well as approximate phase space techniques based on the discrete truncated Wigner approximation (DTWA), which allow the exploration of larger systems sizes, longer times, and even higher dimensions. Additionally, we characterize the dynamical behavior of relevant observables, such as entanglement entropy, quantum Fisher information, and imbalance, and assess their utility in identifying the MBL phase in experiments.

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E01 102 Progress towards a dual species quantum repeater node with a high-finesse fiber resonator* GARRETT HICKMAN, MATTHEW EBERT, TRENT GRAHAM, XIAOYU JIANG, SUDHEER VANGA, RANDALL GOLDSMITH, MARK SAFFMAN, *University of Wisconsin-Madison* We report on progress towards a high finesse fiber resonator to be used in the construction of a dual species quantum repeater node. A high-finesse cavity will be used to allow the state of a single incoming photon to be efficiently mapped onto the collective atomic state of an ensemble of Rb atoms. Entanglement swapping between the Rb ensemble and a qubit defined by the ground state hyperfine manifold of a Cs atom simultaneously trapped within the cavity can then be performed using Rydberg interactions. We describe our work on a preliminary implementation of this system, in which an ensemble of cold Rb atoms is trapped within a high-finesse fiber cavity. This system will allow for the study of Rydberg excitation of Rb atoms in the vicinity of stray electric fields due to surface charges on the fiber tips.

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E01 103 Relative magnitude of "good" and "bad" collisions* BO GAO, *Univ of Toledo* We give a more complete presentation of the quantum Langevin (QL) model for neutral-neutral bimolecular interactions and reactions [1], and use it to provide a general discussion of the relative magnitude of "good" (elastic) and "bad" (inelastic or reactive) collisions. We show that this relative magnitude is determined by the long-range potential, and has the general characteristics of being "bad" at low temperatures and "good" at high temperatures.

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¹Gao, Phys. Rev. Lett. **105**, 263203 (2010).

E01 104 Collisional studies of ultracold $^{23}\text{Na}^{87}\text{Rb}$ molecules* XIN YE, MINGYANG GUO, JUNYU HE, *Chinese Univ of Hong Kong* MAYKEL GONZALEZ-MARTINEZ, ROMAIN VEXIAU, GOULVEN QUEMENER, *Laboratoire Aime Cotton, CNRS* DA-JUN WANG, *Chinese Univ of Hong Kong* We report a series of experiments on collisions of ultracold bosonic $^{23}\text{Na}^{87}\text{Rb}$ molecules in their quantum ground states. First, we studied the collisions of molecular samples with distinct chemical reactivities by making use of the vibrational excitation. We observed very similar loss and heating, regardless of the chemical reactivities. Second, we studied the dipolar collision with induced dipole moments as large as 0.7 Debye. We observed a step-wise enhancement of losses as manifestations of couplings between different partial waves induced by the increasingly stronger dipolar interactions. Our experimental data show nice agreements with the model based on two-molecule complex formation.

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E01 105 Ultracold collisions of spin-polarized $\text{SrF}(^2\Sigma^+)$ molecules with $\text{Rb}(^2S)$ atoms in an external magnetic field* MASATO MORITA, *Univ of Nevada - Reno* MACIEJ B. KOSICKI, PIOTR S. ZUCHOWSKI, *Nicolaus Copernicus University, Torun, Poland* TIMUR V. TSCHERBUL, *Univ of Nevada - Reno* Recent advances in molecular laser cooling have enabled the production of cold, trapped $\text{SrF}(^2\Sigma^+)$ and $\text{CaF}(^2\Sigma^+)$ radicals at sub-millikelvin temperatures. To explore the feasibility of sympathetic cooling of SrF radicals using ultracold Rb atoms in a magnetic trap, we carry out accurate ab initio and quantum scattering calculations of ultracold Rb-SrF collisions. In spite of the significant anisotropy in the interaction potential between Rb and SrF, we find that fully converged scattering calculations on Rb-SrF collisions are possible using a total angular momentum basis including up to 125 rotational states of SrF and up to 3 total angular momentum blocks. We examine the sensitivity of the scattering cross sections to small variations of the interaction potential and use a statistical approach to estimate the success probability of atom-molecule sympathetic cooling.

*This work was supported by NSF Grant No. PHY-1607610.

E01 106 Synthetic dimensions in ultracold polar molecules: From topology to quantum strings* BHUVANESH SUNDAR, MATTHEW THIBODEAU, ZHIYUAN WANG, *Rice University* YUXIN WANG, *University of Science and Technology of China* BRYCE GADWAY, *University of Illinois at Urbana Champaign* KADEN HAZZARD, *Rice University* Synthetic dimensions alter one of the most fundamental properties in nature, the dimension of space. We show that rotational states of ultracold molecules can be used as synthetic dimensions extending to many "potentially hundreds of" "synthetic lattice sites. Microwaves coupling rotational states drive fully controllable synthetic inter-site tunnelings, enabling, for example, topological band structures. We show that interactions leads to even richer behavior: when molecules are frozen in a real space lattice with uniform synthetic tunnelings, dipole interactions cause the molecules to aggregate to a narrow strip in the synthetic direction beyond a critical interaction strength, resulting in a quantum string or a membrane, with an emergent condensate that lives on this string or membrane. We explore the properties of these

discuss the physical origin of the metastability of the spinor BEC system.

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