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**Orbital physics in one dimensional optical lattices**[1]

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We explore orbital physics of fermions and bosons in one dimensional optical lattices. In a system of one dimensional $p$-orbital bosons, various phases, including anti-ferro-orbital Mott, anti-ferro-orbital superfluid and para-orbital superfluid, have been found. Signatures of phase transitions, in particular time-reversal symmetry breaking, in time-of-flight image are predicted. A fermionic ladder system composed of $s$ and $p$ orbitals is proposed, and we find a topological state featuring fractional defects. An equivalent of spin-orbit coupling naturally arises, not requiring artificial gauge field, in this quantum orbital ladder when the $s$ and $p$ orbital states are identified as a pseudo-spin 1/2. Extending this ladder system to two dimensions we find a flat-band protected by parity. The flat-band makes it plausible to study strongly correlated physics in this system. We also discuss the connection of this fermionic ladder to frustrated $\pi$ flux models and spin-orbital coupled fermions.

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