Abstract Submitted
for the DAMOP18 Meeting of
The American Physical Society

**Entanglement between two species of atomic ions and the loophole-free test of quantum contextuality**[1] PENGFEI WANG, JUNHUA ZHANG, MARK UM, YE WANG, TIAN XIE, NAIJUN JIN, JING-NING ZHANG, KIHWAN KIM, Tsinghua Univ, CENTER FOR QUANTUM INFORMATION, IIIS TEAM — We report the entanglement between $^{171}Yb^{+}$ ion and $^{138}Ba^{+}$ ion. First, we prepare all the motional state to near the ground-state by the three-stage cooling of Doppler, the EIT and the sideband cooling on $Ba^{+}$ ion. Then, we apply the Raman laser beams of 355 nm for $Yb^{+}$ and 532 nm for $Ba^{+}$ and create the entanglement of the two ions through a Mølmer-Sørensen interaction. We detect the quantum states of $^{171}Yb^{+}$ and $^{138}Ba^{+}$ by the standard fluorescence scheme. For the $^{138}Ba^{+}$ ion, we shelve an electronic state in $S_{1/2}$ to a state in $D_{5/2}$ by applying a narrow-linewidth laser of 1762 nm. With the entanglement between two species of atomic ions, we can experimentally verify the quantum contexuality without the major loopholes of detection and compatibility. In our experimental realization, it is naturally free of the detection loophole, since the detection efficiencies of both ions are over 98 %. It is also free of the compatibility loophole, since we measure the pairs of the joint observables simultaneously instead of the sequential measurements with totally different wavelength of laser beams for each ion.

[1]This work was supported by the National Key Research and Development Program of China under Grants No. 2016YFA0301900 (No. 2016YFA0301901), the National Natural Science Foundation of China Grant 11374178, 11574002 and 11504197.

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Date submitted: 26 Jan 2018 Electronic form version 1.4