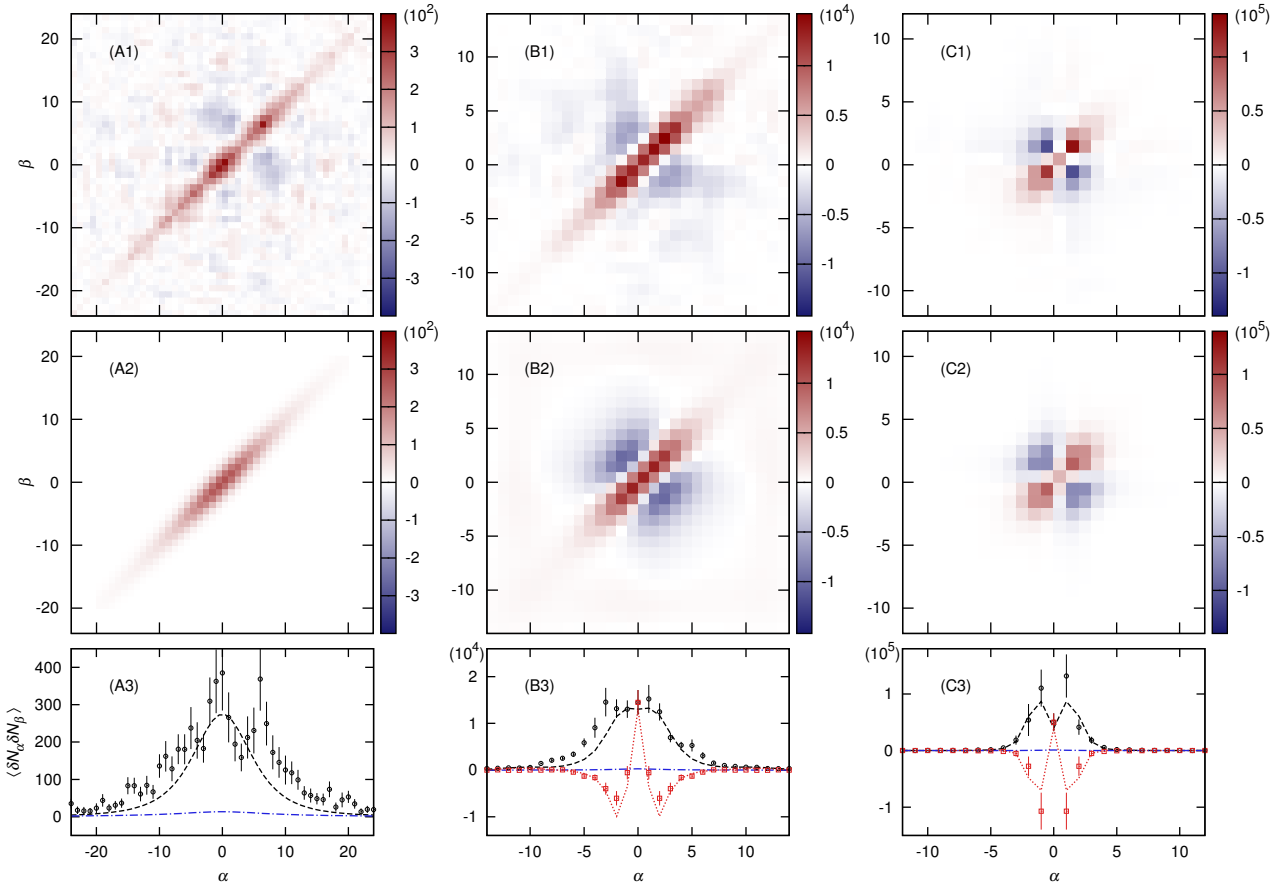

FIG. 1. Momentum correlations $\langle \delta N_\alpha \delta N_\beta \rangle$ for a gas in the IBG regime (Data A, left column), in the qBEC regime (Data C, right column), and in the qBEC-IBG crossover (Data B, middle column). The pixel size is $\Delta/\hbar = 0.15\ \mu\mathrm{m}^{-1}$. The experimental data are shown in the top row. Data A, B and C are compared with the IBG theory, QMC calculations, and qBEC theory respectively, at the temperature of the data determined by independent thermometry methods [26]. The middle row gives the computed momentum correlations. The bottom row shows the diagonal cuts: the experimental data in circles for $\alpha = \beta$ (squares for $\alpha = -\beta$ for Data B and C only) are compared with their respective theory model in dashed (dotted) lines. The error bars are statistical. The dash-dotted lines give the shot-noise limit.

where $\mathcal{F}$ is the dimensionless function given by Eq. (29) of [20], and $B(p,p')$ is evaluated substituting $\nu^{(h)}_{\rho,T}(p)$ by a Lorentzian function of FWHM $\hbar/l_\phi$. The effect of the finite resolution and pixelization is taken into account using Eq. (3). These predictions, plotted in Fig. 1 (C2-C3), are in quantitative agreement with experimental data. Note that the center-of-mass (COM) motion is decoupled from the internal degrees of freedom in a harmonic trap, and the COM fluctations are about twice as large as those expected at thermal equilibrium for this data set [33]. To mitigate their effect, we post select the data by bounding the COM fluctuations. Moreover, since the experimental resolution is not sufficient to resolve momentum scales of the order of $\hbar/l_\phi$, the effect of $\langle \delta n_p \delta n_{p'} \rangle_{\mathrm{reg}}$ on the diagonal reduces the signal that would be expected from bunching alone by almost a factor 10.

Our results provide the first experimental proof of the persistence of bunching in momentum space in a qBEC, as well as the presence of negative correlations, in particular between opposite momenta. The latter contrasts with the behaviour expected for a weakly interacting Bose-Einstein condensate, where Bogoliubov theory predicts the presence of positive correlations between opposite momenta [26]. The absence of opposite-p positive correlations is a clear consequence of the absence of true long range order.

The atom-number fluctuations are strongly reduced in a qBEC because of repulsive interactions and the negative part $\mathcal{F}$, which concentrate on the momentum region $p \lesssim \hbar/l_c$, enforces the reduced atom-number fluctuations by compensating for the diagonal bunching term [20]. In our experiment, however, one may *a priori* suspect that the measured anticorrelations could come from the normalization procedure used in the data analysis. We rule out such a possibility by performing several checks, detailed in the SM [26]. The agreement with theory in our case is ensured by the fact that the fluctuations